

Testing Hydrogen Fuel Purity

Essential for performance, safety, and industrial decarbonization

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Introduction

Hydrogen is vital for industrial decarbonization due to its potential for carbon-free emissions. As a renewable and widely available resource, its demand has tripled since 1975, supported by public policies and investments.¹ Hydrogen fuel is expected to gain traction in high-emission industries, particularly energy providers and transportation.

Hydrogen fuel achieves carbon-free emissions by producing electricity in fuel cells, emitting only water vapor and heat. This process emits no carbon dioxide or other harmful pollutants.² Hydrogen gas can be produced from various resources, including natural gas, biomass, and water, using renewable energy sources like wind, solar, and hydroelectric power.³ Green hydrogen, produced through electrolysis powered by renewable energy, results in near-zero greenhouse gas emissions, making it ideal for decarbonizing sectors.⁴

This white paper highlights the importance of hydrogen fuel purity. Impurities can impact fuel cell performance and safety, necessitating rigorous, standardized testing methods to deliver consistent fuel quality. Hydrogen fuel testing standards and industry collaborative efforts are required to ensure long-term reliability and safety, supporting the broader adoption of hydrogen as a clean energy source.⁵

Hydrogen fuel purity: necessity and standards

Impurities and their impact on hydrogen fuel cells

Hydrogen fuel often contains impurities that can impact its performance and safety. To name a few, sulfur compounds can poison fuel cell catalysts, reducing efficiency and lifespan.⁶ Ammonia can form harmful nitrogen oxides, damaging fuel cells and creating safety hazards.⁷ Nitrogen compounds interfere with electrochemical reactions, decreasing efficiency.⁸ Carbon dioxide and carbon monoxide block active sites on catalysts, reducing power output.^{9,10} Methane causes incomplete combustion, lowering energy efficiency and posing safety risks.¹¹ Oxygen and argon, introduced during sampling, compromise sample integrity.⁶

Impurity levels vary based on feedstock and production methods. For example, hydrogen produced via natural gas steam reforming may contain more contaminants than hydrogen from water electrolysis.¹² Consequently, ensuring quality control has become an urgent priority for manufacturers and users.

International standards for hydrogen purity

Hydrogen fuel purity is governed by several key standards and regulations to ensure its safe and efficient use in fuel cell applications. ISO 14687:2025 is an international standard that specifies the quality requirements for hydrogen fuel, defining the maximum allowable concentrations of impurities such as carbon monoxide, sulfur compounds, and ammonia.¹³ It also outlines the necessary analytical methods and sampling practices. SAE J2719_202003, developed by the Society of Automotive Engineers, provides guidelines for hydrogen fuel quality in fuel cell vehicles, specifying contaminant limits and test methods to ensure reliable and safe operation.¹⁴ In China, GB/T 3634.2-2011 and GB/T 37244-2018 are national standards that set the quality requirements for hydrogen fuel, including maximum impurity levels and detection methods, to maintain consistent fuel quality and safety.^{15,16}

To support regulations, the ASTM Committee D03 on Gaseous Fuels plays a crucial role in developing standardized testing methods for hydrogen fuel purity.¹⁷ This committee is dedicated to promoting knowledge and developing definitions, specifications, classifications, recommended practices, and methods of sampling, analysis, and testing related to gaseous fuels, including hydrogen. The committee's work ensures that hydrogen fuel meets the necessary purity standards for use in fuel cells.

Role of standardization in hydrogen fuel adoption

Standardization establishes consistent quality and safety benchmarks for all stakeholders, including producers, distributors, and end-users. These ensure that hydrogen fuel meets purity levels necessary for efficient and safe fuel cell operation, reassuring industrial and commercial users of the long-term viability and reliability of hydrogen fuel, and facilitating regulatory approval. Moreover, by providing a common framework for production, testing, and handling, standardization encourages integration, investment, and innovation across the supply chain, ultimately accelerating the adoption of hydrogen as a mainstream clean energy source.

Technical challenges and advanced technologies

Sampling and detection difficulties

Hydrogen fuel testing faces significant challenges, especially during sampling. Introducing ambient air can compromise sample integrity, rendering it unsuitable for fuel cells. Contamination can occur throughout the hydrogen supply chain (Figure 1), leading to downstream issues. Some impurities, like volatile sulfur compounds, are difficult to detect due to their tendency to adhere to sample container walls. Further complicating the testing process is hydrogen's small molecular size and high diffusivity, which make it prone to leakage. These sampling challenges necessitate the use of specialized equipment and strict safety protocols.

Additionally, detecting impurities at trace levels is crucial, as even minor contaminants can impact fuel cell performance or cause damage. The testing process demands highly sensitive analytical techniques and robust quality control measures to ensure the fuel meets stringent purity standards.

Advanced technologies for impurity detection

Addressing the challenges of impurity testing in hydrogen fuel goes beyond simple contamination prevention. It requires a comprehensive understanding of the underlying chemical processes, meticulous attention to detail in sampling and analysis, and modern technologies to ensure the highest standards of fuel purity.

Gas chromatography coupled with mass spectrometry (GC/MS) combines the separation capabilities of gas chromatography with the analytical power of mass spectrometry. Its precision and reliability make it an essential tool for quality control in hydrogen production. It allows for the detection and quantification of a wide range of trace impurities, plus the ability to analyze complex mixtures of impurities to help understand contamination sources and improve purification processes.

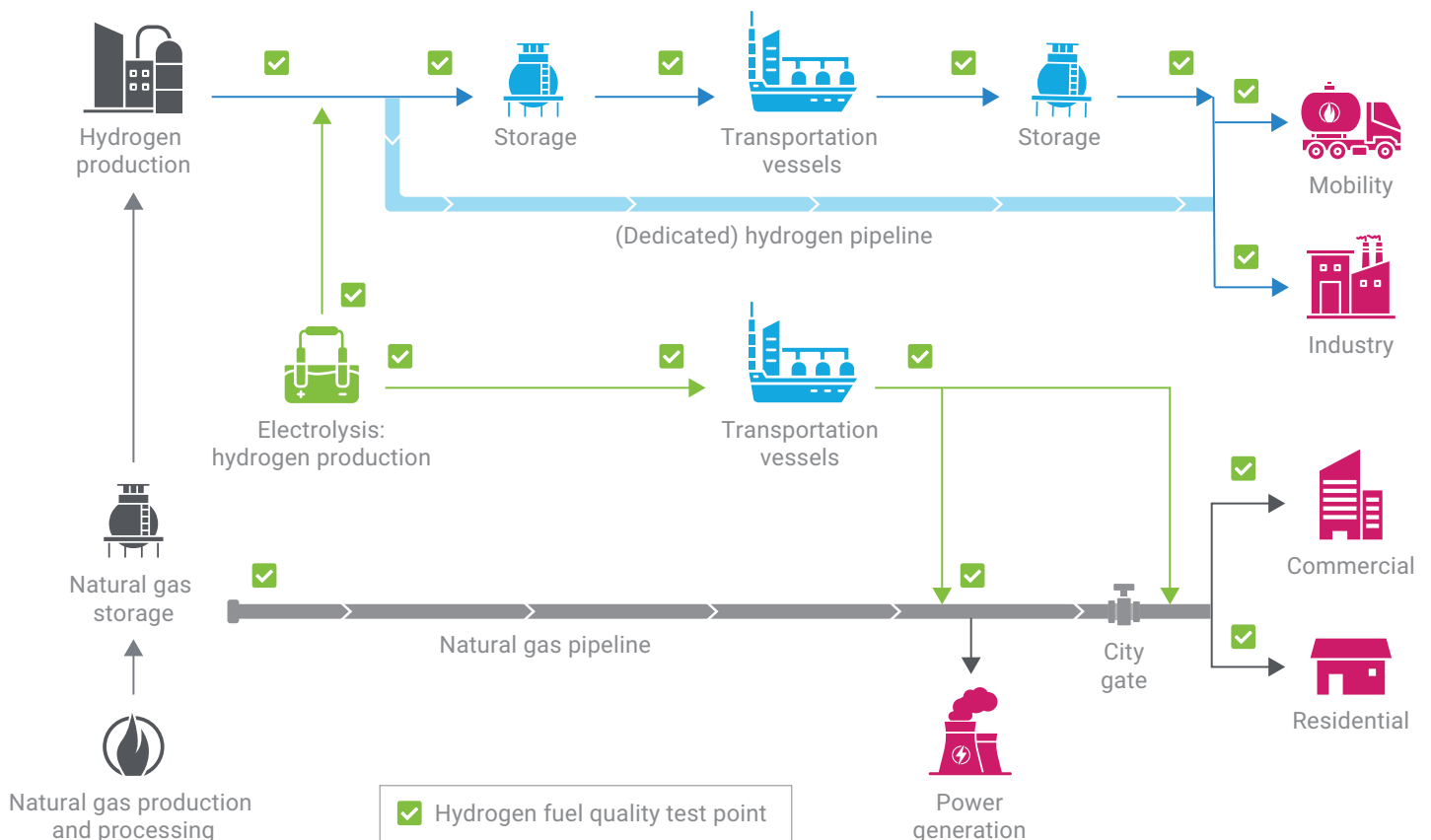


Figure 1. The hydrogen fuel and natural gas blending supply chain.

Contributions and innovations by Agilent

Development of hydrogen analyzers

To support the hydrogen fuel supply chain, Agilent has enhanced its GC-based solutions to address detection needs that go beyond the analysis of permanent gases in hydrogen fuel. The expanded suite of GC solutions is designed to detect trace levels of contaminants such as helium, hydrogen sulfide, ammonia, formaldehyde, and halogenated compounds. These trace contaminants are identified using GC in combination with various detectors, including mass spectrometers, electron capture detectors, sulfur chemiluminescence detectors, and nitrogen chemiluminescence detectors.

Agilent has developed solutions for the analysis of the most common hydrogen impurities. Learn more in our application compendium: [Hydrogen Fuel Testing Solutions](#).

Collaborations with industry leaders

Agilent is collaborating closely with the experts on ASTM Committee D03 on Gaseous Fuels to develop the standardized testing approaches necessary to maintain hydrogen fuel quality across the value chain.

At a regional level, Agilent has also collaborated with China's Sinopec Research Institute of Petroleum Processing (RIPP) to help address the lack of reliable methods for detecting impurities in hydrogen gas. Together, they developed a sophisticated analysis method capable of detecting impurities at parts-per-billion (ppb) level. This breakthrough has already been implemented in China's hydrogen infrastructure, including the first hydrogen fuel vehicle refueling station laboratory, and is accredited by Chinese authorities.

Ensuring reliability and accuracy

Agilent employs robust analytical instruments, including gas chromatography systems, mass spectrometers, and specialized detectors to detect trace-level impurities in hydrogen. By integrating advanced technologies with rigorous standards, comprehensive training, and expert support, Agilent enhances the reliability and accuracy of hydrogen impurity testing, aiding the commercialization of hydrogen fuel.

Future implications and industry impact

Consequences of nonadherence to impurity standards

Failing to adhere to strict impurity standards can severely impact the performance, longevity, and safety of hydrogen fuel cells, leading to reduced efficiency, increased operational costs, and a shortened lifespan. Impurities can be a safety hazard, diminish environmental benefits, and undermine the economic viability of hydrogen fuel cells, slowing market adoption and damaging the industry's reputation. Noncompliance with impurity standards can also result in regulatory penalties. Strict impurity standards are therefore essential for ensuring the reliability and sustainability of hydrogen fuel cells.

Fuel purity impact on the hydrogen economy

Maintaining high-purity standards throughout the hydrogen economy is critical to ensuring the broad adoption of hydrogen technologies, securing investor and public confidence, and advancing global decarbonization goals.

In production, if impurities are not properly controlled, they can contaminate the supply chain, increasing purification costs and complicating logistics, while undermining the economic viability of hydrogen as a clean energy source. On the end-user side, meanwhile, impurities can lead to hazardous conditions, compromising the reliability and safety of hydrogen-powered systems, and potentially slowing market adoption. Importantly, the environmental benefits of hydrogen as a clean energy source can also be diminished if impurities lead to the generation of harmful byproducts.

Conclusion

Hydrogen is crucial for industrial decarbonization due to its potential for carbon-free emissions. Ensuring hydrogen fuel purity is essential for fuel cell performance and safety. Due to the technical challenges in impurity detection, the importance of the right technology and applications to overcome these challenges is paramount.

Continued advancements in testing methods and technologies, along with industry collaboration and standardization, will be vital in maintaining high-purity standards and supporting the growth of the hydrogen economy.

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