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Sensing Safety

Michael Nofal, H2scan, USA, and Robert H. Shelton, H2C Safety Pipe, USA, look at ways to enhance the safety and efficiency of green hydrogen transport.

Hydrogen, the Earth's most abundant and lightest element, is a safe, renewable, and clean resource capable of powering the most energy-intensive industries. When used to produce electricity in a fuel cell, hydrogen's only emission is pure water. And, when hydrogen is generated through electrolysis powered by renewable energy sources such as wind, sun, geothermal, or hydropower, it becomes one of the most promising cornerstones for a clean energy future and essential to achieving the world's net zero goals.

Green hydrogen can be produced at competitive prices in regions with abundant renewable energy, such as the Middle East, North Africa, Chile, and Western Australia. However, these areas are often thousands of miles from the major consumer markets where hydrogen is most needed. This geographic mismatch requires long-distance transport solutions to economically bridge these vast distances, as well as pipelines to efficiently move hydrogen from regional production and distribution centres to end-user locations like major industrial facilities and vehicle dispensing centres.

The fossil fuel economy relies on major pipelines and fleets of tankers that crisscross the globe from where crude oil is produced to refineries and end-user locations. Nearly three million miles of pipeline traverse the US, and an additional 300,000 miles traverse Europe, primarily delivering natural gas, petroleum, and other non-renewable energy resources to homes and businesses. Supplementing and, wherever possible, repurposing this infrastructure for hydrogen will play a pivotal role as nations transition to a hydrogen economy over the coming decades.

A new approach to the safe transport of hydrogen

To address these issues, there is an increasing focus on developing 'midstream' solutions. A number of industry players are developing technologies to transport liquid hydrogen across thousands of miles, from areas where it can be produced economically, and distributing gaseous hydrogen at scale using pipelines that are lower in cost and safer than the options available today.

Ideally, the distribution technology should utilise existing infrastructure, such as oil and gas pipelines, water pipes, sewer lines, and storm drains, to provide critical right-of-way for these projects. This will help companies to avoid stranded assets, reduce initial capital cost and deployment time, and will help stakeholders lower environmental impact and decrease disruption to city streets and roadways.

To be effective, the approach will need to solve the problem of pipe embrittlement, which arises from the contact of hydrogen with steel, and the problem of leakage, which arises from the nature of a gas made of remarkably tiny molecules. In fact, hydrogen can permeate through pipe walls over time and a buildup of hydrogen inside reutilised pipes could lead to dangerous conditions.

Figure 1. *A flange connected to the H2C Safety Pipe test system. Pressurised hydrogen fills an inner carrier pipe made of fibreglass-reinforced polymer. An outer 'safety' pipe contains any leaks; and the H2scan sensor (the grey rectangular component connected through the flange into the space between the two pipes) measures hydrogen concentration within the annulus in real time.*

Testing through prototype

One company working on a solution to these challenges is H2Clipper Inc. (H2C) and its subsidiary, H2C Safety Pipe Inc. The company has developed an H2 pipeline system comprised of a relatively low-cost fibreglass-reinforced polymer pipe inside a containment pipe and an automated system that will purge the containment pipe of any leaked hydrogen.

H2C engineers needed to test their pipeline system to validate installation, monitoring, and safety. A major international hydrogen infrastructure company engaged H2C to build a 10 m prototype system and to test it from October 2023 to January 2024.

The engineers understood that safety depended in part on the ability to detect leaks and to measure how much hydrogen gas was present. They sought a sensitive and precise sensor technology that could measure hydrogen gas in the presence of other gases and required minimal maintenance. Low maintenance was a critical requirement because sensors would be located on pipelines at great distances, making sensor replacement or calibration very costly. The engineers selected sensors made by H2scan.

In 2023, H2C teamed with H2scan, NOV Fiber Glass Systems, and others to build a full-scale prototype and demonstrate the H2C Safety Pipe technology. A 47-page final report was prepared following fieldwork. The results validated the leakage rates previously observed by studies conducted by Oak Ridge National Laboratory and indicated these rates could lead to hazardous concentrations in confined spaces within several days unless adequately addressed. Importantly, the prototype demonstrated that H2C's technology will mitigate such leakage risks and enhance system safety and reliability by continuously monitoring hydrogen concentration levels.

The advantages of safety pipe technology

The double-wall pipe system offers a solution for transporting gaseous hydrogen through existing pipelines and in new installations.

The sensors and the pipe design provide several key advantages:

Enhanced safety and control

The double-wall design isolates any hydrogen permeation or viscous leaks from escaping into the external environment, ensuring this hydrogen is safely removed well before its concentration reaches hazardous levels.

Continuous monitoring of hydrogen concentration levels within the annulus space provides 24/7/365 integrity management. It connects to computer controls, ensuring that issues are detected in real-time, and any areas of emerging concern are promptly addressed before problems occur.

Reduced cost

By enabling the use of existing pipeline infrastructure for hydrogen delivery, the system reduces the cost of acquiring new right-of-way while avoiding the cost associated with abandoning older pipelines. The technology also enables the use of advanced materials, such as fibreglass reinforced polymer (FRP) pipe, which reduces total capital cost and entirely avoids corrosion and embrittlement, two risks concerning a traditional steel pipe.

Accelerated deployment

Retrofitting existing pipelines with this technology approach simplifies the logistical and regulatory challenges associated with new pipeline construction. This includes minimising the hurdles of right-of-way acquisition, which can often delay projects and increase costs.

Traditional detection methods often fall short, particularly in critical infrastructures where even minor leaks can pose significant safety risks.

Environmental benefits

The technology's ability to capture leaks enhances safety and protects the environment by preventing potential hydrogen emissions into the atmosphere, which several prominent environmental groups have shown could be an indirect greenhouse gas, thereby leading to growing scrutiny over hydrogen's diverse environmental impact.

Understanding the application of hydrogen sensors

Hydrogen presents unique safety challenges, while being an environmentally friendly alternative to fossil fuels. Its flammability and propensity to leak undetected through conventional materials and tiny openings require specialised monitoring techniques.

Traditional detection methods often fall short, particularly in critical infrastructures where even minor leaks can pose significant safety risks. Existing sensor technologies include sensors that require a reference gas, consumable components, or periodic calibration. Frequent sensor maintenance is not practical in pipeline applications where the sensors may be located on buried pipeline across hundreds of miles in remote areas.

***Figure 2**. A hydrogen sensor, the HY-OPTIMA® 5031 from H2scan, is located in the annulus between the inner and outer carrier pipes. If the sensor detects that unsafe levels of hydrogen gas have leaked into this space, then a control system automatically initiates a purge of the annulus with an inert gas.*

For this system, the engineers selected H2scan's solid-state sensor to provide real-time continuous measurement of hydrogen levels. The sensors detect hydrogen specifically without cross-sensitivity to other gases. An auto-calibration capability eliminates the need for periodic maintenance. The sensor does not require a reference gas or consumable components.

Conclusion

H2C Safety Pipe technology may represent a significant advance for hydrogen distribution. By addressing safety concerns, leveraging existing infrastructure, lowering cost, optimising efficiency, and facilitating the transport and distribution of hydrogen, the double-wall safety pipe approach promises a smoother transition towards a hydrogen-based economy.

As the hydrogen economy continues to evolve, the role of advanced technologies becomes increasingly vital. Sensors must provide accurate, real-time monitoring of hydrogen levels to detect leaks, ensure safety, enhance operational efficiency, and support the widespread adoption of hydrogen across diverse applications - from transportation to industrial processes and beyond. Sensors are the enabling technology that will help the global community realise the vast potential of hydrogen as a transformative, clean energy solution.