John Anderton, Senior Simulation Consultant, Atmos International, UK, explores overcoming the sustainability challenges of hydrogen fuel transportation with leak detection.

In an effort to accelerate decarbonisation and map out a route to net-zero emissions, hydrogen became a prominent conversation topic at the recent COP27 summit. With a focus on the introduction of a hydrogen economy to the developing world, hydrogen (and green hydrogen production in particular) has been suggested as the solution to stunted economic growth and trade relations.[1]

Financial costs vs environmental savings

Just as there's no shortage of hydrogen itself (it accounts for at least 70% of all atoms in the universe), there's been no shortage of literature on hydrogen following the COP27 summit. Whether it be in discussions about hydrogen's role in the creation of nuclear fusion as an energy source, engineers in Australia identifying a process that uses soundwaves to boost green hydrogen production, or Rolls-Royce testing green hydrogen as jet fuel for the aviation industry, hydrogen can already be proven as a net-zero substitute for conventional fuel. But do the financial challenges of hydrogen fuel production and transportation offset its environmental savings?[2,3,4]

As mentioned at COP27, hydrogen is a sector that isn't fully established, requires financing and has a complex

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value chain, which raises questions about whether the energy industry is ready to start producing and transporting hydrogen fuel.[1] Additionally, the process for producing certain types of hydrogen, such as brown or grey hydrogen (Figure 1) can ultimately overshadow the net-zero emissions promised by the end product.[5] Pair this with the fact that there is debate surrounding the feasibility of hydrogen to heat UK homes, for example, and it raises questions into how sustainable hydrogen is as a universal carbon neutral fuel.[6]

However, there are a number of uses for which hydrogen has already been identified as a suitable fit and, when it comes to new ways of producing energy, hydrogen remains one of the key areas gaining momentum. Part of the European Commission's REpowerEU plan, for example, has an expectation that 20.6 million t/yr of hydrogen will be imported along pan-European pipeline corridors by 2030.[7]

Taking this into consideration, I will work with an understanding that a transition to hydrogen fuel is inevitable, and look at how the sustainability challenges of hydrogen can be optimised through effective leak detection.

Sustainability challenges

While hydrogen energy has distinct advantages as a net-zero solution, there are still risks involved in hydrogen fuel transportation.

Hydrogen molecules are smaller than natural gas molecules, for example, so hydrogen fuel can not only leak more easily but potentially leak more product.[8] It's worth noting that the intended goal of hydrogen fuel can be partially counteracted in the event of leaked product too.

A recent study by the UK government's Department of Business, Energy and Industrial Strategy (BEIS) details the implications on global warming if hydrogen fuel leakage occurs. Hydrogen not only becomes an indirect greenhouse gas (GHG) when it reacts with other GHGs, but it affects the composition of the atmosphere by way of climate warming and impacting air quality. A key finding in this BEIS study suggests hydrogen is twice as powerful a GHG as was initially thought.[9]

For this reason, those handling hydrogen fuel should consider the previously mentioned sustainability risks when considering how to transport the product, and look to the following as prerequisites to overcome those challenges.

What's the safest way to transport hydrogen?

When it comes to transporting any gas or liquid, there exists a whole host of options for getting the product from A to B. Barges, tankers, and tugboats can transport fuel across a range of water sources, while railroad tankers utilise the existing railroad infrastructure to deliver product. Ultimately, pipelines consistently remain the safest means of transporting any gas or liquid due to their infrastructure that often uses the shortest and most economic route.

Pipeline infrastructure's role

As hydrogen gas blends are introduced to gas pipelines, it's important to consider what, if any, repurposing needs might be required to an existing network's infrastructure. As previously mentioned, hydrogen has a significantly different molecular makeup to a natural gas and because hydrogen's atoms are so small, they can be absorbed by the metal interior of the pipeline transporting it, causing cracks to emerge in the pipeline through a process called hydrogen embrittlement. For these reasons and many more, it's vital that pipeline operators receive training to understand what impacts the shift to hydrogen will have on the pipeline.

Hydrogen has a much lower energy density than natural gas, so repurposing pipelines previously used for natural gas to transport hydrogen is not straight-forward as pipeline capacity will be impacted. Using simulation tools for both design and operation can mitigate the risks associated with the transition from natural gas to hydrogen.

Simulation software like Atmos SIM enables operators to model all aspects of the pipeline's infrastructure, providing

Color code	Brown	Grey	Blue	Turquoise	Pink	Yellow	Green
Energy source	Coal or lignite	Natural gas	Any non-renewable energy source	Methane	Nuclear energy	Solar power	Any renewable energy source
Process of production	Gasification	Steam reformation	Steam reformation and carbon capture and storage (CCS)	Pyrolysis	Electrolysis	Electrolysis	Electrolysis
Highest to lowest greenhouse gas emissions							
Lowest to highest acceptance level							

Figure 1. Colour chart detailing the different types of hydrogen and their production methods.

them with a better understanding of how the pipeline network will cope with the introduction of hydrogen fuel blends.

If we look to Figure 3 as an example, capacity for this pipeline network is restricted by supply locations, network topology, and demand pressure requirements. Capacity will also be affected by the transition from natural gas to hydrogen, but simulation software can accurately predict future capacity for hydrogen and hydrogen blends.

The same simulation model can be used as an online decision support tool to accurately predict the current or, by using look-ahead models, the future state of the network.

Figure 4 illustrates what would happen to the demand pressure on a pipeline if there is a supply interruption: the pressure continues to fall but hasn't triggered any pressure warnings or alarms after 12 hours. If actions are taken before the alarm level is reached, the pipeline can continue to deliver gas to the customer without pressure violation.

Figure 2. Atmos SIM can use data delivered from the field through a supervisory control and data acquisition (SCADA) system for advanced applications on a gas pipeline, such as leak detection and batch tracking.

Figure 3. A theoretical gas transmission network.

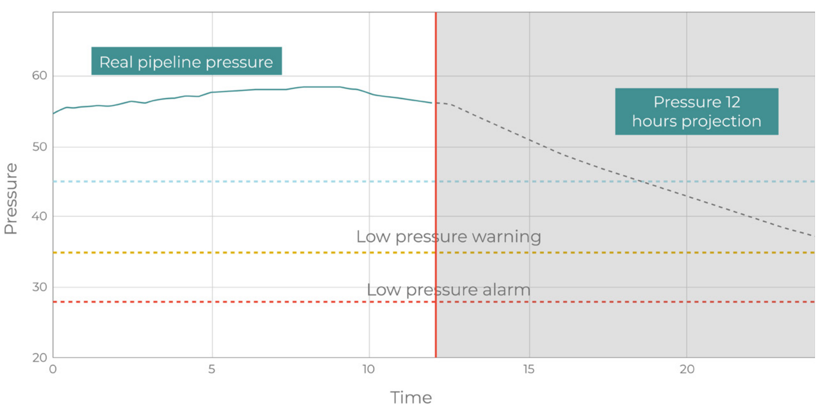

Figure 4. A 12 hr forecast from a what-if look-ahead of a decrease in pressure in the event of a supply interruption.

Leak detection

A multitude of factors can cause a leak on a pipeline. There's the possibility of corrosion (which has already been mentioned in the context of hydrogen embrittlement), excavation and outside force, operational causes, natural causes, and more.

Many leaks are identified by people on a liquid pipeline where the spilled products can be seen by the naked eye. In the case of hydrogen gas, it is odourless, colourless and flammable which, if left undetected during a leak event, can have catastrophic effects on the surrounding area and the atmosphere itself. For this reason, a real-time leak detection system made of advanced hardware and software is vital for safe hydrogen fuel transportation.

Leak detection software such as Atmos Wave can use negative pressure waves to detect leaks accurately and with a minimal false alarm rate during steady-state, transient and shut-in conditions. Additionally, simulation software like Atmos SIM can detect leaks effectively by incorporating the statistical algorithms used by Atmos Pipe, the world's first statistical volume balance system.

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