Hydrogen gas analysis and detection technology

© Insplorion AB | **Hydrogen gas sensor**

By **Stephen B. Harrison, sbh4 consulting**

Hydrogen gas analysis and gas detection is performed daily in many applications. However, traditional sensors used to measure hydrogen suffer from several 'pain points'. But a breakthrough might be on the way. Insplorion, a gas analysis technology innovator based in Sweden, has developed a new technique that will transform the way hydrogen is measured. Their system can enable improved safety and more reliable process control.

The default sensor for measuring hydrogen gas for process control applications is a thermal conductivity detector (TCD). The instrumentation works very well in binary systems when the background gas is known. In this situation, the electronics and software can be configured to measure the hydrogen concentration accurately. However, in applications where the background matrix gas changes or additional gases are introduced, the TCD is less suitable.

For flammable gas detection in the range of 1 to 2%, hydrogen leaks are generally detected using a pellistor which relies on catalytic oxidation of the hydrogen as a measurement principle. The technique is ideal for detecting hydrogen leaks into air, but when hydrogen leaks must be measured in an inert atmosphere of nitrogen or helium, the pellistor arrangement must be modified to introduce an air or oxygen stream to enable the catalytic oxidation reaction.

An electrochemical cell can be used to measure ppm-level traces of hydrogen in process control or leak detection applications. However, the electrochemical cell can quickly become saturated with hydrogen and measurement in the percentage range is not possible. Furthermore, maintenance and replacement of electrochemical cells is time consuming and expensive.

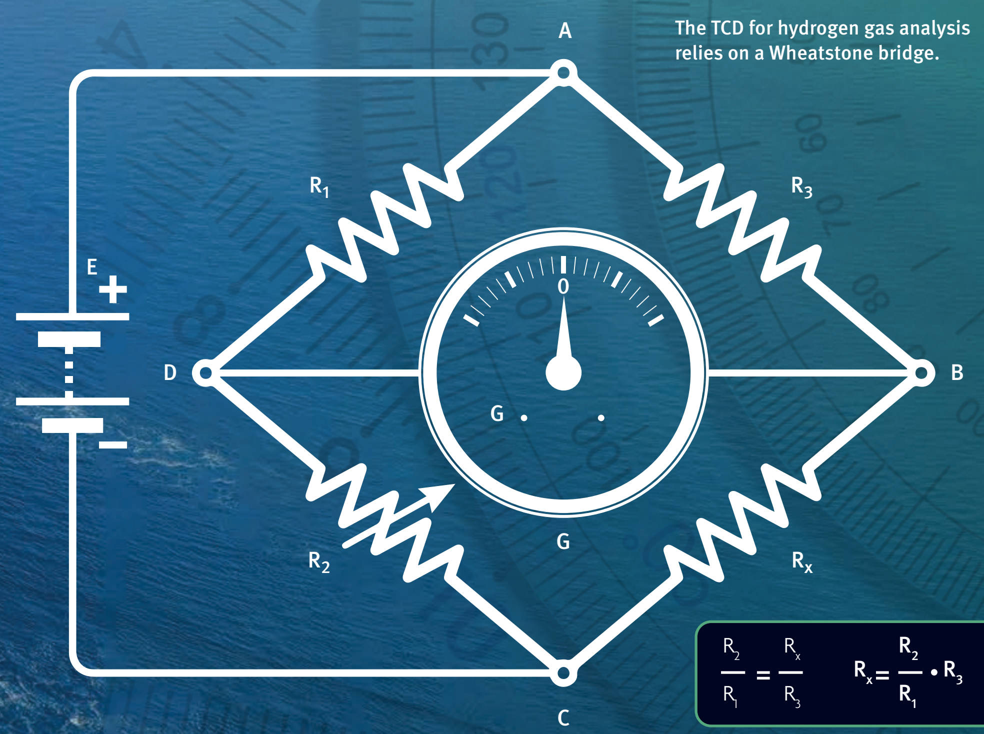
"The sensor technology our devices use is an optical technique utilising a Pd-based material that can measure hydrogen accurately in binary or complex gas mixtures. The problem with measuring hydrogen with conventional optical techniques such as infrared is that they are not good at analysing diatomic molecules," says Johan Rask, CEO of Insplorion. "They work well for carbon dioxide and methane, where the molecule is made from different atoms, and especially where carbon is included in the molecule. But they struggle to pick out gases such as hydrogen where two hydrogen atoms bond together to form the gas."

He continues to say that "our gas analyser can be configured to operate in the ppm (parts-per-million) or percentage ranges to cover the full span of applications related to safety and process control. We have demonstrated detection speed (t90) down to a few seconds and excellent hydrogen selectivity, even in the presence of other combustible gases. Also, the sensor does not require any additional gas for its operation. So, it can be used in a vacuum, or with air, oxygen, or an inert background gas. Market feedback has confirmed that it will enable a transformation in the way engineers can design hydrogen production, storage, and distributions systems."

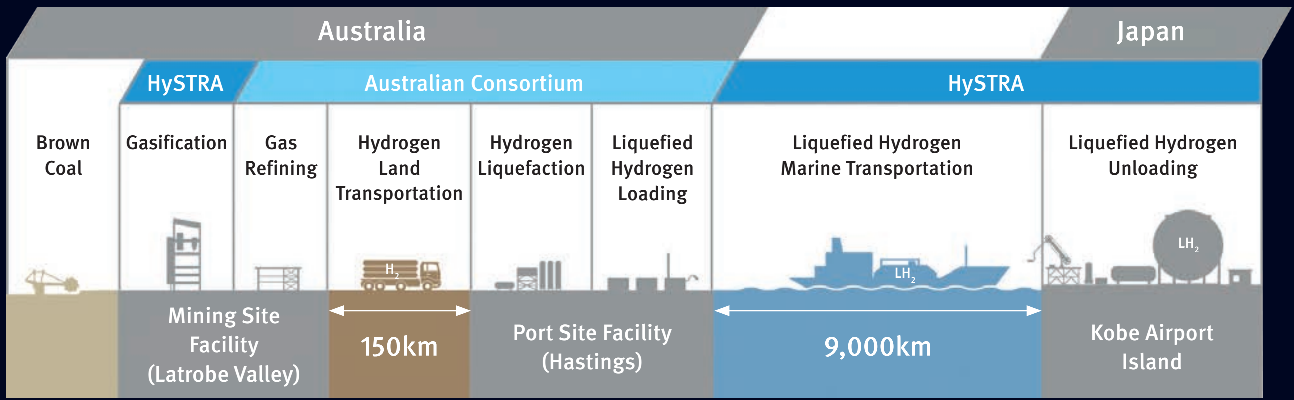
Electrolyser & fuel cell process control

Electrolysis of water yields hydrogen gas at the cathode and oxygen gas at the anode. However, the oxygen is likely to contain about 1% of hydrogen and the hydrogen will contain traces of oxygen. As the electrolyser ramps up and down,

LNG tanker at terminal



The TCD for hydrogen gas analysis relies on a Wheatstone bridge.



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for example to respond to fluctuations in variable renewable power availability, the concentration of hydrogen in the oxygen stream can rise and fall.

At around 4% hydrogen in the oxygen, the gas mixture becomes potentially explosive. To avoid this hazard, the hydrogen concentration is continuously measured. If the hydrogen concentration rises to around 2%, process intervention would generally be required to keep the gas mixture concentration out of the flammable range. The oxygen and hydrogen gas mixture leaving the electrolyser contains a high amount of humidity from water in the electrolysis process.

"TCDs have been used for electrolyser process control in the past. However, we are confident that the benefits of our technology will be recognised," says Elin Langhammer, CTO, and Co-Founder of Insplorion. "We envision real-time process monitoring through elimination of a sampling system. Our approach aims to give the electrolyser operator immediate access to accurate data from each cell stack module."

Safe operation of fuel cells also relies on gas analysis. For example, on a PEM fuel cell, hydrogen is humidified prior to being fed to the anode. The humidity is essential to preserve the functionality of the membrane. Unreacted, humid hydrogen flows from the anode and is recycled to ensure efficient use of the hydrogen feedstock.

On the other side of the PEM fuel cell, air is humidified and sweeps over the cathode. As hydrogen ions transfer across the membrane, they react with oxygen in the air to form water. Nitrogen from the air does not participate in the chemical reactions. The gas stream leaving the cathode is therefore a mixture of oxygen, nitrogen, and humidity.

However, if the membrane becomes damaged there is the possibility that hydrogen gas will transfer into the cathode air stream. Rask confirms that "measuring the undesirable transfer of hydrogen across a PEM fuel cell membrane is safety critical. The application is non-trivial from a technical perspective, but Insplorion's hydrogen sensor has the potential for in-situ monitoring."

Hydrogen leak detection for a safe hydrogen production

Hydrogen electrolysers have well defined gas detection requirements, in addition to process control gas analysis needs. Small-scale electrolysers are often built into a container, which is an enclosed space. Larger systems are also generally installed indoors to protect the equipment from dust and rain. The indoor and containerised locations of electrolysers make a combination of passive measures such as ventilation and active systems such as gas detection especially important.

The main technical standard related to gas detection for electrolysers is 'ISO 22734-1: Hydrogen generators using water electrolysis process'. The standard makes guidance about escalating layers of protection. The first lines of defence when detecting a slight elevation in hydrogen concentration would be to implement additional ventilation.

Detection of a more severe gas leak would trigger an emergency shutdown of the electrolyser. The electrical power supply is isolated, and a flow of inert nitrogen gas is activated. This purges the internal space of the electrolyser, and the nitrogen, oxygen and hydrogen gases are vented to a safe location outside the containerised system. Gas detection cannot avoid a gas leak, but it can reduce the risk.

Containerised steam methane reformers (SMR) are also common for on-site hydrogen production. The SMR converts either methane to syngas which is a mixture of carbon dioxide, carbon monoxide and hydrogen. The whole system operates at elevated pressures meaning that flammable gas leaks are possible and gas detection is essential.

Pellistors are the standard types of flammable gas detector sensors used in the low percentage range. They rely on catalytic oxidation of the leaked flammable gas with oxygen from the surrounding air to generate an alarm. The pellistor technology can detect hydrogen, carbon monoxide and methane but cannot differentiate between these three gases.

"The implication is that there is no granular information provided to the SMR operator to support troubleshooting of the leak and initiate an appropriate maintenance response," says Langhammer. "On the other hand, our hydrogen sensor can identify hydrogen gas molecules. It is therefore able to speciate between various flammable gases present in reforming systems and help to pin-point the source of the leak."

Hydrogen leak detection in inert gas backgrounds

For maritime applications, safety related to hydrogen storage and usage is likely to leverage lessons from CNG and LNG. Maritime natural gas systems are often shrouded with nitrogen gas to create an inert environment. This prevents a natural gas leak forming a flammable mixture with air. This is a commonly used approach to maintain safety at sea.

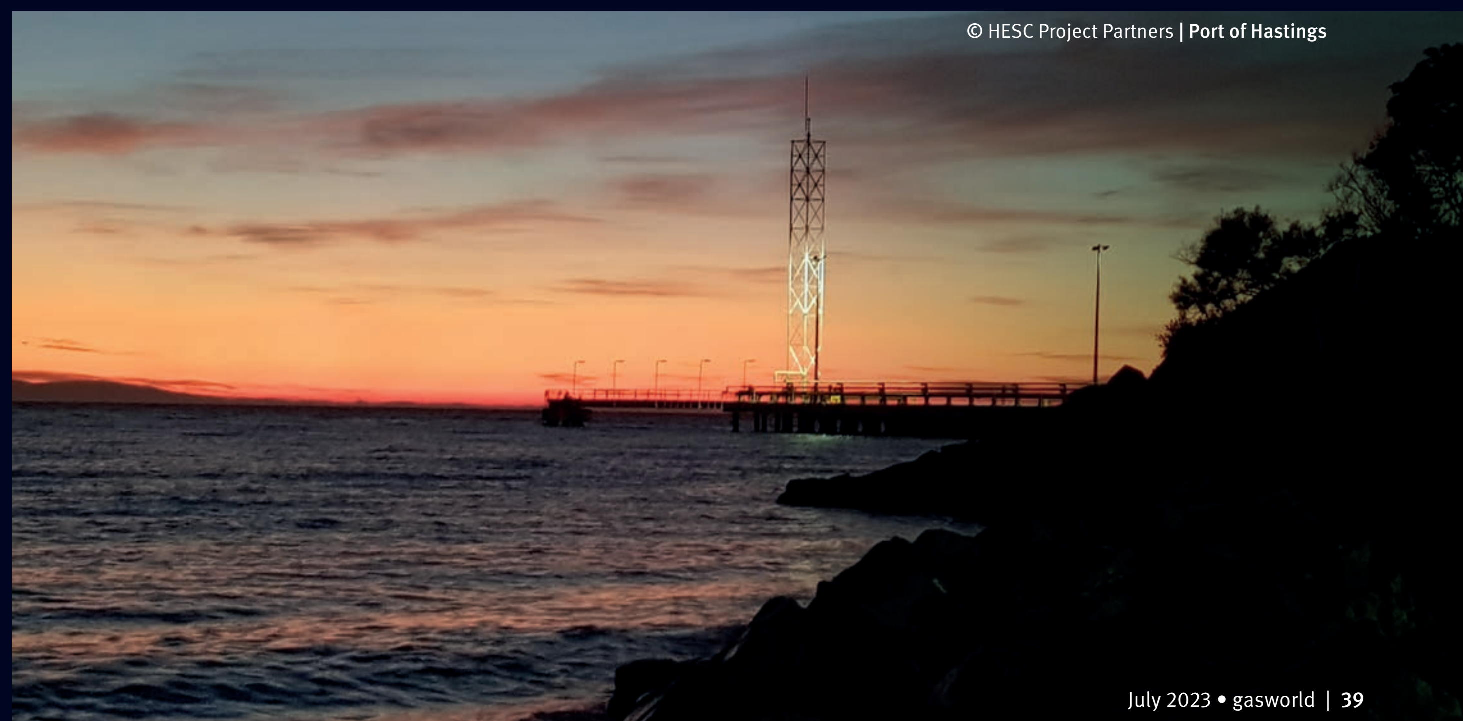
Rask believes that "a similar approach for the storage and utilisation of hydrogen in the maritime sector is expected to be used. According to DNV, rules for the use of hydrogen in fuel cells are under development and will be included in a future amendment to the regulation for alternative fuels, such as LNG (IGF Code). Further, fuel storage and fuel supply systems must comply with the related chapters of the IGF Code, which currently covers LNG and compressed natural gas (CNG)."

The catalytic oxidation reaction that takes place in a pellistor-type gas detector relies on oxygen from the air to combine with the flammable gas. If hydrogen, or another flammable gas, is released into an inert gas atmosphere, the pellistor gas detector must be fed with air or an oxygen stream to enable the oxidation. Whilst this is possible in theory, in practice this complicates the system and increases the risk of system failure. This is the case for several traditional gas detection sensors on the market, leading to engineering challenges in how to design safe and efficient hydrogen applications.

> "... measuring the undesirable transfer of hydrogen across a PEM fuel cell membrane is safety critical"

Liquid hydrogen is increasingly being considered and piloted as a fuel on board buses, trucks, ships, and aircraft. In all these applications, safety is critical. Shipping liquid hydrogen cargoes as an energy vector is also being investigated. It has been piloted in the HySTRA project, shipping liquid hydrogen from Australia to Japan on the Suiso Frontier.

Rask says that "the regulations and standards related to liquid hydrogen storage for various applications are under discussion and in development. However, our market dialogue confirms that there is significant interest in the use of our gas analyser to detect a hydrogen leak in inert nitrogen gas background." gw



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