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Hydrogen Sensing for Safety and Reliability

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GETTING A SENSE OF HYDROGEN

COVER STORY

David Meyers, H2scan, USA, discusses the importance of hydrogen sensing within the emerging hydrogen economy.

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According to Forbes, the hydrogen economy will soon be ready for takeoff given the strong global investment and desire to make hydrogen a leading sustainable source of energy.' Hydrogen sensing will play a critical role in making this goal a reality. This article will provide insights into the use and impact of hydrogen sensors, both in current applications as well as within the emerging hydrogen economy.

What is a hydrogen sensor?

Hydrogen is the lightest and most abundant element in the universe, and one would think that developing a device to measure its concentration in a gas or liquid would be simple. Unfortunately, this is not the case; it took many years of research and development - from the early days when canaries were used to detect explosive gases in mines. The first sensor of the modern age was developed in 1926 by Dr. Oliver Johnson of Standard Oil Co. His design measured the heat created by the presence of combustible gases in air. This thermal conductivity technology is still used today, along with a range of new gas sensor technologies that have been developed over the last 100 years. Each of these technologies (e.g. gas chromatography, catalytic bead, laser gas analysis, solid-state, etc.) were developed to address unmet gas sensing needs, and there are many issues to consider when applying these technologies to hydrogen sensing.

What to consider when selecting a hydrogen sensor for industrial applications?

Industrial sensing applications generally have challenging performance and operational requirements that must be met over a range of environmental and other conditions. Care must be taken to ensure that the selected sensor and underlying technology works for the intended use, for example:

- Sensor performance may seem like a straightforward specification, but the devil is in the details. For example, a quoted measurement accuracy of 0.1% could be the maximum error, or it could be the one sigma error, or it could only be valid at room temperature and one atmosphere of pressure. Also, the quoted accuracy specification may only be met after calibration for a specified period before drifting out of specification.
- If other gases are present in the stream being measured, they could impact sensor accuracy. For example, carbon monoxide (CO) in a hydrogen stream can corrupt the hydrogen measurement when using certain gas sensing technologies. One must understand the gas stream make-up and consider using a hydrogen-specific sensor to avoid cross-gas sensitivities.
- From a total cost of ownership perspective, sensors should be selected to minimise or avoid calibration, maintenance and service if possible. Some hydrogen sensor technologies have consumables, such as calibration gases, that must be periodically replaced. Also common is the need for sensor calibration to maintain long-term accuracy. One should understand the calibration interval and the associated costs, especially for remote or hazardous locations, or whether the system needs to be shut down for this maintenance. Beyond the upfront cost of the sensor and its installation/connectivity, one should consider the total cost - including the cost of training

operation support professionals.

- If the sensor is not reliable, sending a service team to an oil platform or remote pipeline location takes a great deal of time, effort and expense. Sensor technologies requiring numerous mechanical parts and components, such as gas extraction systems to measure hydrogen in liquids, are often not well-suited for these applications. One should strive for a long life, with a goal of over 10 years.

- Hydrogen is an explosive gas, and a small spark can cause it to explode within certain concentration levels. There are certifications, such as ATEX, to ensure that sensors work safely in hazardous environments. Sensor compliance to these certifications is critical to ensure safe operation.

Where are hydrogen sensors being used now?

The largest hydrogen user today is refining and chemical production. One such application is hydrocracking, which uses hydrogen sensors to ensure efficient processing. One of the challenges of oil processing applications is gas streams that can contain multiple other gases, such as hydrogen sulfide (HS). These gases can reduce the measurement accuracy if the sensor is not a hydrogen-specific design. Also, the sensor needs a fast response time to ensure tight process control when concentration levels fluctuate, in order to achieve optimal process efficiency.

Another common application for hydrogen sensors is area safety monitoring for the detection and mitigation of hydrogen build-up in a closed environment. For example, in data centres and utilities, battery back-up systems are used to provide instantaneous back-up power.

Figure 1. Hydrogen sensor (in green) mounted to an electricity transformer.

Cost-effective energy storage solutions such as lead acid batteries are commonly used, and can release hydrogen during recharging. A similar application is hydrogen fuel cell forklifts that could potentially leak. In both applications, hydrogen sensors are generally mounted in the ceiling to trigger alarms and enable fans to evacuate hydrogen at concentrations well below the lower explosion limit of approximately 4%.

One hydrogen sensor application that many people are unaware of is transformer monitoring to improve electrical grid reliability. Power on the grid is distributed using large transformers that convert high voltage to a lower voltage for end users. These devices are filled with oil to keep them cool and provide electrical isolation. If there are faults or overheating in the transformer, the oil will break down into hydrogen and other gases. If faults persist for too long, the transformer can explode and cause a fire, or injure people.

Hydrogen sensors are used to continuously measure hydrogen levels in the oil to determine the need for maintenance or to take the transformer offline.

Why are hydrogen sensors important to the hydrogen economy?

The goal of the hydrogen economy is to use hydrogen to help decarbonise the energy supply chain - from production to consumption. As stated in the 'Road Map to a US Hydrogen Economy', safety is paramount.? This is a precondition of any energy carrier, but as hydrogen is a greenhouse gas (GHG), leak detection is critical for its wide deployment.

Most hydrogen produced today is from fossil fuels, and is referred to as grey hydrogen because one of the byproducts is carbon dioxide (COz). The hydrogen economy goal is to produce green hydrogen from renewable energy and to adopt fuel cells, gas turbines or other means for the subsequent conversion back into electricity. Hydrogen is also planned to be distributed through gas pipelines for industrial uses, home heating, and as a transportation fuel. Hydrogen sensors will play an important role across these applications to ensure safe and effective operation, as well as the detection of harmful leaks.

What is next for hydrogen sensors?

There are numerous near-term hydrogen economy applications that require hydrogen sensors for safe and effective operations.

The production of green hydrogen uses electrolysers that convert water into hydrogen and oxygen using a process called electrolysis. Some analysts are predicting that up to 85 GW of electrolyser-based hydrogen production will be deployed by 2030. If there are issues in the electrolyser, hydrogen can leak into the oxygen output side, creating an explosive mixture. Detection of this failure mechanism is critical to ensuring the safe operation of these systems.

Hydrogen will also be blended with natural gas and sent through the gas pipeline as part of the decarbonisation plan. Home and industrial heating is a large user of natural gas, and replacement electricity in the near-term will be a challenge. To put this into perspective, natural gas delivers five times the energy of the electric grid in the UK.

To use hydrogen safely, all gas pipeline infrastructure, burners and metering in the gas distribution network must be aligned to support a mixture of methane and hydrogen. Gas blending stations will use a

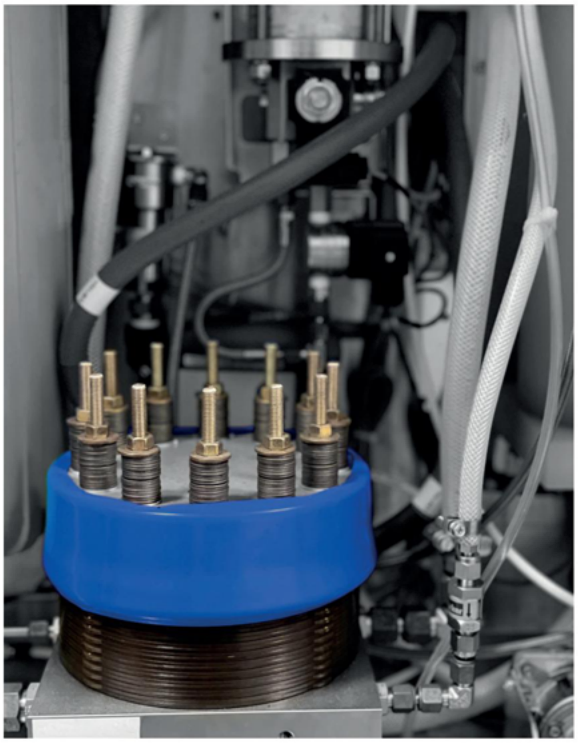

Figure 2. An electrolyser is used in the manufacture of hydrogen. The industry is working to produce green hydrogen using electrolysers and clean energy sources.

hydrogen sensor to ensure that the mixture is the right concentration for safe operation. Along the distribution pipeline, hydrogen sensors could be used to confirm downstream concentration and support energy metering and customer invoicing. Finally, hydrogen sensors could be used for home safety, much like a smoke alarm, to ensure that leaks are detected early before hazardous concentration levels are reached.

In transportation, there has been success in large vehicles using hydrogen, and there have been regional pilot programmes in small vehicles as well. These vehicles use fuel cells which use hydrogen and oxygen to make electricity, and output water. If hydrogen is not fully utilised or ti leaks into the exhaust water, there can be risks associated with the out streams from these devices. In addition to large vehicles and personal vehicles, fuel cells are also being used for hydrogen-fuelled forklifts. Once again, hydrogen sensors will be used to detect hydrogen leaks to ensure safe operations in this application.

Conclusion

The future of the hydrogen economy is bright and wil be an important part of global decarbonisation initiatives. Hydrogen sensors will play a critical safety role in many aspects of the development and eventual deployment of a global hydrogen economy - in industrial applications as well as in the home.

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