Gas detection for safety around hydrogen electrolysers and SMRs

By Stephen B. Harrison

Red is the colour of danger. We know this intuitively from traffic lights and safety signage, where it means 'prohibition'. According to the *EN 1089-3*, red is also the colour assigned to hydrogen gas cylinder shoulders. A red shoulder also identifies other flammable gases. But, with appropriate measures such as risk assessment, HAZOP and the implementation of appropriate mitigating actions, like gas detection, the risks associated with hydrogen production can be minimised.

Intelligent process protection

The use of gas detection must be combined with a process that asks the question: how did this leak take place and what would be a suitable reaction?. This is known as 'a cause and effect matrix'. It is often the case that a specialist gas detection company will work together with the plant designer and operator to implement the right technology and safety control systems for the process and the gases that it contains.

Beyond the hardware design and construction, engineering expertise and operational insight are required to devise safety management systems which link the gas detection alarms with likely causes and appropriate mitigation. For some gas alarms a simple response such as closing an actuated valve may be suitable to eliminate the hazard. Or, a full emergency shut down of the process and evacuation may be required if the combination of alarms indicates an extremely hazardous situation. This is how the 'cause and effect matrix' adds value to the design of the safety equipment and related emergency response procedures.

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SMR safety

Energy gases such as hydrogen and methane demand specific attention due to the danger of fire and explosion. For a leak to air, hydrogen has an LEL (lower explosive limit) of 4% and a UEL (upper explosive limit) of 75% – that is an extremely wide range. And spark ignition from electrical components or maintenance activities is an ever-present risk. The combination of these hazards adds up to a situation where the need for explosimeters and flame detection systems becomes clear.

The SMR also produces carbon monoxide, which is both flammable and toxic.So, the use of a system with multi-gas detectors including sensors that are specific to carbon monoxide might be appropriate. Wearable gas detectors as part of the operator's daily PPE would also be common practice around hydrogen plants. This is partly because plant facilities, such as: laboratories, filling stations and compressor rooms are generally indoors in a confined space. These enclosed buildings may also present the risk of oxygen deficiency if the inert gas nitrogen is used to drive pneumatic process control systems.Ventilation, in addition to gas detection would be an appropriate mitigation.

François Ampe, Product Line Manager EMEA at Teledyne Gas and Flame Detection, explains that, "gas detection works very well in enclosed buildings where there is no wind to disperse a gas leak. But in open outdoor spaces a leak can be diluted to an undetectable level by a strong wind current."

Ampe explains how flame detectors can help in those situations, "On a steam methane reformer there is generally a natural gas pipeline feeding the plant and a hydrogen pipeline exporting product from the plant. We are surrounded by flammable gases. Flanges and valves in the pipework are potential gas leak points and the plant risk assessment may have determined that each one should be fitted with a gas detector close by. However, prevailing atmospheric conditions might mean that the methane or hydrogen gas leak is blown away from the gas detector and no alarm is registered – it can happen. This is where a flame detector might spot the problem before it escalates to a major explosion. In French, we call this complementary approach 'ceinture et bretelles'. I think that in English it is known as 'belt and braces'."

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"Another energy gases example might be a high-pressure methane compressor on CNG tube-trailer filling system. Using multiple gas detection devices and flame detectors, the operator can use a 'voting system' to escalate between a visual alarm, an audible alarm and an automated system shutdown, according to the number of gas and flame detectors that have been activated. This can help to minimise disruptive 'false-alarms' and simultaneously ensures that a truly hazardous situation is flagged as quickly as possible – to protect lives and plant assets."

Hydrogen electrolyser gas detection

Throughout history, there have been some high-profile safety incidents related to hydrogen. The crash of the airship Hindenburg in 1937 is an oft-cited example of how this gas has the potential to be extremely dangerous. And the recent explosion at the OneH2 hydrogen plant in North Carolina on 7th April 2020 is a pertinent reminder that the hazards associated with this gas have not diminished over time. But, with good safety management systems we can do many things to minimise the risks from the hazards that are inherent in the production and distribution of hydrogen.

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Steam methane reformers have been the default technology for large-scale hydrogen production for several decades. However, electrolysers are now scaling up and making in-roads into this space. These plants have a specific set of gas detection considerations. Christopher Braatz from McPhy in Germany says, "Hydrogen electrolysers are often located indoors in an enclosed space. This makes a combination of passive measures such as ventilation and active systems such as gas detection especially important."

There are various international technical standards that we follow when considering the safety of electrolyser installations, for example the *ISO 22734-1: Hydrogen generators using water electrolysis process*. Braatz adds that, "We use these international standards in combination with a detailed risk assessment which our engineers conduct with the electrolyser operator."

"The first lines of defense are to implement good ventilation and install a hydrogen gas detector. We might even go further to consider oxygen gas detection. Furthermore, automated safety control systems at our installations invoke the appropriate actions in the event of a gas leakage alarm. For example, a severe alarm would trigger an emergency shutdown of the electrolyser. This shutdown follows the same procedure that would also be used to make the electrolyser safe for routine maintenance. Quite simply, the electrical power supply is isolated, and the inert gas nitrogen is used to purge the internal space of the electrolyser. The nitrogen, oxygen and hydrogen gases are then vented to a safe location."

Certification of hydrogen electrolyser equipment and facilities

Many types of hydrogen electrolyser operate at elevated pressures in the order of 20 bar. This has the benefit of reducing their footprint and increasing the electrical current density to produce more hydrogen from a smaller unit. As such, this type of electrolyser comes >>

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>> under the scope of the *European Pressure Equipment Directive (PED) 2014/68/EU*. One of the consequences of this is that they must be certified by a 'Notified Body' before they are sold from the manufacturer to the operator.

Founded in 1866 as a steam boiler inspection association, TÜV SÜD is a prime example of such a Notified Body with a long-standing pedigree in pressure vessel inspection and certification. Through rigorous internal qualification management and training procedures, a Notified Body such as TÜV SÜD, will employ several experts who are competent to carry out the inspections and certification according to the PED. Guntram Schnotz of TÜV SÜD Industrie Service in Filderstadt, Germany is one such person.

According to Schnotz, the equipment certification must be followed by a review of the installation at the operator's site. He says, "TÜV SÜD are approved by the European Union to certify equipment under the PED which is to be put into service anywhere in the EU. The next stage in the process becomes national. As a German entity, we are authorised to conduct the inspection and certification of the final installation which the operator is responsible for, if it is installed in Germany."

The critical link in the chain between the production of a hydrogen electrolyser and its use will be the hand-over documentation which will include a user manual. Schnotz adds that, "Many of the safety management

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cases will be implemented into the equipment design. However, some residual risks will exist, and these must be identified in the operating manual so that the user of the equipment is able to implement appropriate mitigation. Gas leak hazard mitigation is one such example. The operating manual is likely to refer to the requirement for ventilation and gas detection."

"When we are inspecting an installation prior to certification, we review the hand-over documentation and check that all the required precautions have been correctly incorporated into the final installation. Our goal is to make sure that nothing is left to chance because we know how hazardous hydrogen can be". H2V

About the author

Stephen B. Harrison is celebrating 30 years involvement in industrial gases this year. He was previously global head of Specialty Gases & Equipment at Linde Gas, and spent more than 15 years with BOC Gases. He is now a consultant at manging director at sbh4 GmbH.

If you are interested in receiving a white paper covering gas detection on a wider range of industrial gases facilities, contact the author.