Gas detection for air gas production facilities

By Stephen B. Harrison

In the hospital or at home, medical oxygen can be a life saver. During the coronavirus pandemic, millions of Covid-19 patients worldwide have been administered with medicinal oxygen to support their recovery. In the right hands, oxygen is highly therapeutic – but during its manufacture it can present hazards which must be mitigated to ensure the safety of personnel and plant assets.

Flammable, toxic and asphyxiant gases are processed 24 hours per day in the industrial gases sector. A myriad of preventative processes, such as HAZOP and risk assessments are undertaken to minimise the operational risks. Also, real-time monitoring techniques such as gas detection are used to sound the alarm if a gas leak does take place. Fixed sniffers can protect equipment, wearable units can protect people, and portable units can support maintenance activities.

The most appropriate mix of gas detection equipment is largely influenced by the potential hazards of the gases onsite. Across medical oxygen production operations and cylinder filling, gas detection has a major role to play. Investment in safety is a mindset which can take the form of low-risk process selection, reliable equipment specification and encouraging behavioural or cultural best practices. The installation of gas detection instrumentation to sound the alarm before a situation escalates to a dangerous level, can also play an essential role in a mix of mitigation and prevention strategies. The links between the gas detection equipment and automated responses or human behaviour are also essential to work through.

> "Investment in safety is a mindset which can take the form of low-risk process selection, reliable equipment..."

With business continuity in mind, gas detection can also play an important role in protecting profits. Black swan events, such as the coronavirus pandemic, remind us that investing in prevention is often money wisely spent.

Medical oxygen production – gas detection around the ASU

Billions of dollars of CAPEX in the industrial gases sector is tied up in air separation units (ASUs). They produce bulk liquid oxygen which is then delivered to hospitals or vaporized to gas and filled into high pressure medical oxygen gas cylinders.

In these two processes, gas leaks have the potential to cause oxygen enrichment from oxygen leaks and oxygen deficiency from nitrogen or argon leaks on the ASU. Shin Tsushima, Vice-President, ASU Engineering for Matheson Tri-Gas in Texas, summarises the situation for ASU gas detection. "When implementing a gas detection system on an ASU, the essential things to consider are personnel safety and equipment protection. For plant protection requirements, the most typical systems are fixed gas detectors which are located according to the results of a robust risk assessment. If these fixed detectors identify a leak, safe shutdown of the relevant equipment is the first and the best choice."

Tsushima adds that, "Portable type gas detectors for oxygen, toxic gas and flammable gases are also essential for protecting personnel as they move around the site. When a personal detector alarms, moving out of an enclosed space, walking across the wind direction, radioing the control room for help or donning breathing apparatus could be life-saving responses. Furthermore, preparation and training in a suitable evacuation plan which can be executed in the event of a gas detector alarm is one of the most important site emergency procedures."

And not forgetting... safety on the the APU

In modern ASUs the crude argon column is designed to separate all the oxygen from the argon. A second high-purity argon distillation then takes place to separate the nitrogen from the argon. In older ASU plant designs, it was more common to process the crude argon in a separate argon purification unit (APU).

The APU is the unsung hero of industrial gases. When it comes to profitable operations, the APU can make or break the P&L. And when it comes to safe operations, the APU is worthy of the same level of respect as the bigger plant items onsite.

"To consider the gas detection requirements on the APU," says Tsushima, "the methodology is the same as every other unit – consider the risks presented by the gases being processed." Quite obviously, we have argon. Like nitrogen, argon is inert and a leak will displace oxygen in the atmosphere which can be very hazardous, potentially causing oxygen deficiency and anoxia. The risks are increased if the leak takes place in a confined space with inadequate ventilation. This hazard can best be detected with several fixed gas detectors which are permanently sniffing for oxygen deficiency."

Tsushima adds, "Thinking beyond the obvious presence of argon, we must dig deep into the workings of the APU to identify other potential hazards. The crude argon feed to the APU contains about 2.5% of oxygen and about 0.5% of nitrogen. The main function of the APU is to remove the nitrogen and oxygen to yield high purity argon."

The ASU's crude argon distillation column has done as much of the oxygen and argon separation job as reasonably possible and as a next stage, other technologies must be used to remove residual gases. The most common technique is to use a catalytic 'deoxo' unit: a reactor fed with hydrogen gas which reacts with oxygen in the crude argon in the presence of the palladium catalyst. This reaction releases heat and the temperature at the outlet will be about 150°C. The flow of hydrogen to the deoxo reactor is controlled so that a small excess of hydrogen (around 1%) is present in the outlet gas stream. The resulting argon, nitrogen and hydrogen mixture is distilled to yield high purity argon and the residual hydrogen and nitrogen mixture is generally flared.

Summing up, Tsushima concludes that, "In this scenario we have: a source of pure hydrogen (perhaps a gas line fed by vaporized liquid hydrogen from a bulk storage tank or a high-pressure bank of hydrogen cylinders); the presence of heat; a combustion-type reaction taking place in the deoxo reactor; and an open flare."

"Bear in mind that hydrogen has a lower explosive limit in air of 4% and an upper explosive limit of 75% – that's a very wide range. Putting all these things together, it becomes obvious that a leak of hydrogen near the APU could be very hazardous and spark ignition is an ever-present risk. One or more fixed gas detectors sniffing for hydrogen leaks are therefore required."

Sensors make sense

François Ampe, Product Line Manager EMEA at Teledyne Gas and Flame Detection in France, has a depth of expertise in designing customised gas detection systems.

He says, "There is a wide gulf between an off-the-shelf wearable single gas detector for oxygen deficiency and a fully integrated gas and flame detection system. In my career, I have worked with these two extremes and many solutions in-between. There is a common link between a portable device, which might cost only a few hundred euros and a fixed gas detection system mounted in a rugged ATEX housing costing a few thousand Euros, and that link is the gas sensor: every gas detection unit, large or small, will have a gas sensor."

Depending on the gases it is sniffing for, this sensor will be a very clever piece of electrochemistry, some modern solid-state electronics or a highly sensitive optical device. In each case, the technology is packed into a tiny space about the size of a few coins stacked on top of each other. The sensor is the 'nose' of the gas detector as it continuously sniffs the atmosphere.

Oxygen is generally detected using an electrochemical fuel cell. Ampe says that, "measuring oxygen enrichment and deficiency is achieved using the same sensor, so a leak of oxygen which causes oxygen enrichment or a leak of nitrogen or argon which would cause oxygen deficiency can be detected using similar devices." Oxygen, nitrogen and argon are three of the main hazardous gases processed on an ASU.

Gas detectors are also used in a range of other industrial gas production processes. The principles are similar, but details of the gas sensor technology change. For many flammable gases with a carbon atom in the molecule, such as methane which is a common feedstock for SMRs and propane which can be used as a refrigerant gas, an infrared sensor can be used.

Ampe explains that "hydrogen is also a flammable gas, but unlike hydrocarbon gases, the hydrogen molecule contains no carbon atoms and is therefore not infrared active."

"So, for hydrogen gas detection a specialist catalyst bead type of sensor must be used. This is the kind of essential knowledge that we offer to our customers when we help them select the most appropriate gas detection system." gw

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 and Managing Director at sbh4 GmbH.

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