Smelling trouble?

Stephen B. Harrison, Nexant Energy & Chemicals Advisory, Germany, considers the importance of gas detection in downstream plants to process and employee safety.

Devastating explosions and a blazing fire ravaged the Philadelphia Energy Solutions refinery on the east coast of the US on 21 June 2019. One of the explosions was strong enough to launch a 17 t steel process vessel 700 m across the Schulylkill river. The preliminary findings of the US Chemical Safety and Hazard Investigation Board indicated that a propane leak from a pipe elbow on the gasoline alkylation unit was the root cause of the incident. The time between the leak and the initial ignition was approximately 2 minutes. Three subsequent explosions followed over the next 22 minutes and the fire raged for more than 24 hours.

The incident led to the intended closure of the refinery after more than 150 years of downstream operations. At 335 000 bpd of crude oil refining capacity, it ranked as the tenth largest refinery in the US and the largest on the eastern seaboard.

Figure 1. Flammable or toxic product transfer from land-based storage to and from barges or tankers is common on inland waterways in Central Europe.

Figure 2. Refineries and tank farms require flammable and toxic gas detection.

Figure 3. Refined products or chemicals transfer from bulk storage to road tankers requires gas detection.

This case demonstrates that the risks posed by flammable gases in refineries are more than theoretical: they present a real and present danger that must be monitored with suitable gas detection techniques to protect people, assets and entire facilities.

Whilst some may like to think of these incidents as 'one-offs', they are not. Soon after, on 27 November 2019 at Port Neches in Texas, a pair of explosions at the Texas Petroleum Chemical plant also led to a major fire and prompted the evacuation of approximately 50 000 people. The cause there was possibly a butane gas leak associated with the butadiene process unit.

Gas detection across the broad HSE agenda

It was fortunate that the incidents in Philadelphia and Texas resulted in no deaths. It is equally lucky that explosions and fires at refineries in Vohburg in Germany in 2018 and Sannazzaro de'Burgondi in Italy in 2016 also resulted in no fatalities. But toxic and inert gas leaks can pose hazards which are equally as dangerous, but much subtler than these sensational events.

Fixed gas detection systems are used as an early warning system on refineries and storage terminals to prevent fires and explosions in the event of a flammable gas leak. Increasingly, they are now also being used to check for toxic gases – such as the BTEX group of benzene, toluene and xylene – to minimise health risks to the plant operators. High level readings of flammable or toxic gases can be set to trip process equipment or set flow control valves to a safe position and thereby minimise the risk of an incident and the associated losses, injuries and long-term health risks. Gas detection is essential for protecting the health of workers in addition to protecting plant and assets for process safety.

Entry into confined spaces generally takes place in refineries during inspection, maintenance and turnaround events. Prior to entry into the confined space, it must be released as safe through a permit to work system. This is generally done using a portable gas detection system. The gas sensors are measuring residual levels of toxic gases such as hydrogen sulfide and carbon monoxide, or depleted levels of oxygen which might be caused by high levels of the asphyxiant gas nitrogen, which is often used to purge pressure vessels prior to inspection.

A toxic gas cloud is likely to be invisible. Some toxic gases such as ammonia and hydrogen sulfide are detectable by their odour, but many others, such as carbon monoxide, are not. Nitrogen accumulation resulting in oxygen deficiency is completely invisible and odourless – but extremely dangerous. Gas detection systems have a vital role to play in supporting our human nose to protect workers in such situations.

The application of gas detection is now increasingly moving beyond the health and safety agenda to environmental monitoring. Hydrocarbon gas leaks on the refinery present a flammability risk on the one hand and an environmental concern on the other. The detection of hydrocarbon gas leaks on refineries is regulated by the US Environmental Protection Agency (EPA) according to Method 21 – 'determination of volatile organic compound leaks'. It prescribes suitable distances between the potential leak point and the gas detector and proposes suitable gas detection technologies such as photoionisation, infrared absorption or catalytic oxidation. All these sensor types are common in various modern chemical-based fixed and portable gas detection systems.

Increasingly, gas detection systems are also being used for environmental monitoring of volatile organic compound (VOC) emissions from valves, flanges, pumps, compressors and pressure relief devices. Fixed detectors can monitor for leaks 24 hr/d and are replacing handheld portable systems that require operators to walk the site checking for leaks. This results in cost-savings in labour and demonstrates to the environmental regulators that improvements in monitoring are being made. Furthermore, through continuous improvement in process equipment with maintenance for leak reduction, the monitored results can also demonstrate a long-term reduction in VOC emissions. The result is better for the environment and better for the process economics: leaks represent waste. This application is an emerging reason to augment existing fixed gas detection systems with new devices.

Fixed chemical detectors, open-path optical systems and portable gas detectors

For expansive areas, such as a tank farm or the route of a gas pipeline over flat terrain, an open path gas detection system might be ideal to cover the long distances involved. However, in a complex refinery process field where distillation columns, scrubbers, reaction vessels and piping are obstructing the line of sight, the open path system is unlikely to have the ideal surroundings to operate to its full potential. For a location that has been assessed as a high-risk leak area during a HAZOP study, such as a gas compressor or volatile liquid pump, a fixed location gas detector may be more suitable.

Portable gas detection systems which are worn by operators as they move around between locations can be effective to warn personnel to avoid areas where toxic, flammable or inert gases have accumulated. Fixed systems are designed to detect gas leaks as they happen or soon after. However, whether they are fixed or portable, gas detection systems based on chemical sensor technologies are limited to monitoring gases close to the location where they are situated. Open path gas detection systems, on the other hand, can detect flammable gases in the line of sight where they are installed and can cover a vast range.

A rainbow mix of solutions

Each system has its strengths and limitations. Given the differences that exist, it might be considered that each system has its purpose and a combination of strategies is the most effective solution. Fixed and portable chemical-based gas detection systems require frequent bump testing and periodic calibration – and that incurs some ongoing maintenance effort and cost. Portable systems are not easily integrated into site alarm systems and the device batteries require recharging in a docking station, making them unsuitable for uninterrupted long-term use. Open path systems can have comparatively high one-time installation costs and are limited in the number of toxic gases that they can detect. Despite the comparatively high cost per system, due to their large range, a single pair of open path optical gas detectors may be able to do the job of many fixed chemical detectors and the maths can quickly add up to cost savings.

Equally, each system has some merits. For example, a portable gas detector is just right for short-term entry into a confined space such as a reactor vessel that requires inspection. It is also ideal for use in areas that will be temporarily occupied such as gas exploration drilling rigs or construction sites. On the other hand, a fixed gas detector, e.g. for checking for hydrogen sulfide close to a flanged joint on a desulfurisation Claus reactor, would be ideal for integration into the site alarm network. And, an open path system is a great option for monitoring the perimeter of the process field to detect a hydrocarbon gas cloud that may be moving towards the administration building or control room.

As with many aspects of refinery health, safety and environmental management, the optimal solution is not a black and white either/or situation. Rather, a colourful rainbow of technologies will lead to the best possible protection of people, assets and facilities. Instead of opting for a single system, most refinery and hydrocarbon processing sites will find it optimal to employ a combination of solutions. Portable devices for site-walks and the release of confined spaces to issue a permit to work for maintenance; fixed systems for leak detection around high risk equipment and integration to the site alarm system; and open path systems for large zone coverage and to validate the alarm signals generated by other fixed gas detection systems.

Digital developments

Digital innovations have the potential to minimise the shortcomings of some of the systems. For example, increased diagnostics and intelligence can minimise the frequency of false-alarms caused by rogue readings on chemical sensors or physical obstructions such as birds or trucks passing through an open path gas detector beam.

Each of these gas detection systems lends itself to the increased use of wireless communications technology, allowing easier installation and more effective communications. For portable gas detectors, this enables peer notification of alarms combined with remote monitoring which allows for shortened response time, plus accountability of users. They also enable voice communications or 'man-down' communication from the user to a base location. For fixed units, it means that multiple detectors can be set up to act as one large mesh network and some units may be selected as communications gateways to the site safety management control system.

Using wireless communications technology can also make installation of new systems to augment existing hard-wired systems extremely fast and cost-effective. On an established refinery or storage terminal, the idea of digging and laying new cable trenches for hardwired fixed gas detection systems would immediately raise a long work list of permitting, engineering management of change reviews, HAZOP studies and costly groundwork. The expense, complexity and timeline of the installation would demand a strong benefit case to proceed.

But in the modern digital world of Industry 4.0, the use of battery-powered wireless fixed gas detection units can simplify the installation tremendously. If they can communicate with an existing site communications protocol, such as the HART open protocol communications technology, their installation and configuration can be achieved in a matter of hours or days, not weeks or months.

Ten years ago, the thought of using a battery powered wireless gas detector would have either been a technical fantasy or the costs for a pilot unit would have been prohibitive for general applications. Today, sophisticated power management systems to increase the battery life to an acceptable multi-year period and high production volumes of the required electronics have combined to mean that the costs of these devices have tumbled. Unit for unit, they are still more expensive than a wired device of a similar quality and specification, but compared to hardwired devices, the breakeven point for an installation now typically lies in the order of 3 – 5 detectors.

The economics mean that for smaller augmentation projects with relatively few fixed gas detectors, the hardwired option is likely to be cheaper in terms of materials and installation costs. But the tipping point is often around four devices. Also, as with all technology, costs will continue to fall, meaning that in the future it is possible that even for small jobs the wireless system will be favoured.

All this being said, in some cases the installation project cost is not the deciding factor. If an installation is required immediately, then the wireless system may be the only option that is quick enough to be installed in an acceptable time window. Consider that the environmental regulator or a safety audit has mandated that operations be terminated until corrective action is taken. The daily costs of non-operation can be many multiples of the cost of the gas detection installation, so speed will be the governing factor, not the project cost. In these cases, a battery-powered wireless option which can quickly integrate into site communications protocol means that digitalisation is facilitating advances in process safety, employee health and environmental protection.