Modes of protection

Edward Naranjo, MSA Safety, USA, reviews ethylene detection methods and assesses their potential to mitigate the consequences of gas leaks.

Few gases match the broad use of ethylene in modern society. Ethylene is a starting material for the industrial synthesis of linear polymers, aldehydes, and a whole host of other major chemical products. Plastics, plasticisers, surfactants, food additives, and fibers are products of this major building block. At the end of 2006, global ethylene capacity was 121 million t (28 million t in the US alone)[1], making ethylene the most produced organic compound in the world.

Ethylene is highly reactive and explosive over a wide range of concentrations. As shown in Figure 1, ethylene poses a fire risk over a larger span of concentrations than benzene and several short chain alkanes.

In addition, ethylene has among the lowest minimum ignition energies of industrial gases, a burning velocity that is approximately 35 - 60% greater than that of methane, and a high flame temperature. Such combination of physical properties contributes to making ethylene a significant workplace hazard. In the UK, for example, ethylene is classified as a dangerous fluid as defined in schedule 2 of the Pipeline Safety Regulations 1996 (PSR)[2].

Because of the hazards associated with ethylene leaks, safety equipment manufacturers have developed detectors that combine fast response, reliability, accuracy, and selectivity. Market trends toward increasing plant utilisation have also prompted manufacturers to develop detection devices of comparably small size and low overall cost.

Several detection techniques are available to monitor ethylene; catalytic and infrared (IR) detection are the most established, while others like ultrasonic gas leak are emerging. This article compares various sensor principles and evaluate their fit, given their states of development, to ethylene handling.

Detection technologies

Catalytic gas detection

A common technique for establishing the presence of ethylene is catalytic gas detection. Catalytic detectors employ

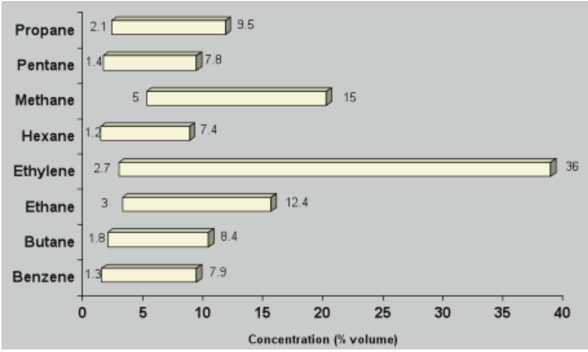

Figure 1. Explosive concentration ranges for select gases.

catalytic combustion to measure combustible gases in air at fine concentrations. As combustible gas oxidises in the presence of a catalyst, it produces heat and the sensor converts the temperature rise to a change in electrical resistance, which is linearly proportional to gas concentration. A standard Wheatstone bridge circuit transforms the raw temperature change into a sensor signal.

The simplicity of catalytic detector design belies several strengths that have made them a mainstay of fire and gas safety applications for over 50 years. Catalytic detectors are robust, economical, reliable, and self compensating to changes in the environment like humidity, pressure, and temperature. They are also easy to install, calibrate, and use. Once in place, the detectors can operate for years with minimum maintenance, requiring only periodic gas calibrations to verify operation. Because the catalytic combustion reaction is non-selective, catalytic detectors can be used for monitoring several target gases across a wide range of applications. Catalytic sensors are suitable to detect ethylene in concentrations well below the lower explosive limit.

IR gas detection

IR detection depends on the ability of certain molecules to absorb light at wavelengths that are characteristic of molecular structure. The absorption characteristics are defined by molecular vibrational energies associated with stretching, bending, or rotations. In general, functional groups absorb radiation in characteristic wavelength bands. Ethylene, for example, exhibits distinctive spectral features in the 3.3 µm region.

Combustible IR instruments employ a dual wavelength technique. In order to prevent distortions produced in the background due to source ageing, contamination of the optical surface, or response to other gases, absorption at a particular band is monitored with respect to a reference measurement. Reference wavelength bands are chosen in a region of the IR spectrum where there is minimal absorbance of the gas of interest. Hence, using the differential absorption technique, both active and reference channels are equally attenuated when there are contaminants present in the IR beam.

The advantages of infrared combustible gas detection are well known. Infrared detectors can operate in oxygen deficient or enriched areas, are resistant to corrosion, and are fail safe. Failures like beam block or defective light sources are revealed, enabling operators to restore the device to full operation. Additionally, IR detectors require no routine calibration. Maintenance consequently involves occasional cleaning of dust screens and external optical surfaces and removal of any debris that may impair access of the target gas to the sampling chamber.

Infrared units configured for ethylene are also non-selective, hydrocarbon detectors that show varied response to other hydrocarbons. Exposed to 10% lower explosion limit (LEL) methane, an ethylene point detector will measure approximately 65% LEL ethylene. Ethane, propane, and other gases with strong absorption in the near IR yield high percentage LEL outputs at low concentrations on ethylene infrared units.

Combustible IR detectors can be both point and open path. IR point type devices are used to detect ethylene in various concentration ranges, typically arranged in a three dimensional array or in duct mounted for heating ventilation air conditioning (HVAC) systems. In contrast, an open path device uses an IR source coupled to a remotely sited receiver. These devices can be used to measure ethylene along the perimeter or across a process area when installed at a defined spacing in one direction. In addition, open path detectors designed for use in ventilation ducting (short path length) can be placed in air intakes, including gas turbine enclosures.

For ethylene monitoring, open path detectors should be arranged in spacing spanning 1 m for areas of high congestion to 9 m for areas with low levels of congestion.[3] The degree of confinement and obstruction is a significant factor in the propagation of a flame front and a fire or detonation's hazard potential. At distances of 1 – 9 m, depending on level of congestion, overpressures resulting from flame speeds of 100 m/s will be than 150 mbar (2.2 psi), the threshold for major structural damage[4].

Typical alarm levels for point IR and catalytic detectors are 20 – 60% LEL while that for open path detectors is 0.6 LEL-m (20% LEL over 3 m for medium congestion).

When selecting a detector for monitoring ethylene, one must consider the potential for exposure to background gas, the operating temperature, and oxygen level in the atmosphere. Assuming the environment is reasonably devoid of other hydrocarbon gases, ethylene point detectors should do well for detecting unignited escapes of the gas.

Ultrasonic gas leak detection

Another non-selective method for detecting ethylene is ultrasonic gas leak detection.[1,2] Ultrasonic gas leak detectors respond to gas leaks by measuring the changes in background noise. As gas escapes from a pressurised vessel, it emits broadband sound, the ultrasonic component of which can be measured by a microphone. The ultrasonic sound pressure level (SPL) is proportional to the mass rate (leak rate) at a given distance and thus provides a measure of the leak's severity. The leak rate in turn is mainly dependent on leak size and gas pressure.

The advantages of ultrasonic gas leak detection include instant detection of pressurised gas leaks and imperviousness to changes in wind direction or gas dilution. Ultrasonic detectors provide broad area coverage and do not require transport of the gas to the sensor. Another advantage of the devices is that their performance can be verified with live gas leaks during commissioning. Using an inert gas, operators can

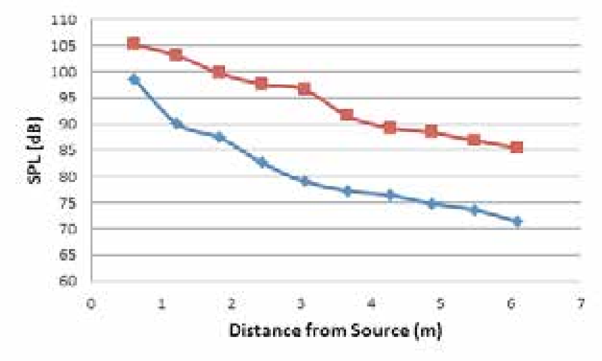

Figure 2. Sound pressure level (SPL)as a function of distance for ethylene leaks*.

carry out simulations of gas releases of a known leak rate and test the response of the detectors in potential locations.

Ultrasonic gas leak detection is restricted to the high pressure leaks (> 10 bar or 145 psi) necessary to produce acoustic emissions at levels substantially higher than the background noise. Most importantly, ultrasonic gas leak detectors do not detect the presence of gas, but rather the leak itself.

Ultrasonic gas leak detectors respond well to ethylene. As shown in Figure 2, a gas leak detector can provide early warning to small leaks at distances of about 10 m, affording wide area coverage in variety of noise environments.

Conclusion

As a key building block for the petroleum industry, ethylene is produced, stored, and transported in quantities that few other industrial products can match. To provide for its safe handling, chemical and petroleum companies must ensure the prevention of failure of pipeline and process and storage facilities that could lead to gas releases and fires and explosions. As the infrastructure to enable ethylene handling is deployed, ethane based ethylene producers will invariably need detection techniques that are better suited to supervise the process fluid.

Several of these techniques are described in this article. Infrared gas detection provides high integrity and reliability in point and open path configurations, essential for safety applications. Since optical gas detection is a physical technique, high target gas concentrations for prolonged periods and changes in oxygen level do not degrade sensor performance. Most importantly, IR devices are fail safe.

The acceptance for these techniques for ethylene monitoring is gathering momentum as organisations assess the type of gas release scenarios that might be present in the carbon capture and storage process. The techniques, however, are not a panacea and likely need more work in order to improve the performance of detection instruments, particularly over temperature extremes, for the most rigorous applications. The best strategy appears to be to deploy these techniques in combination, so that the devices may cover a broader range of gas release scenarios while mitigating the vulnerabilities of these techniques. No doubt, where safety of the workforce and the public requires a high level of reliability and integrity, detection diversity has an important role to play in continuing efforts to improve process safety. HE

Notes

* (■) mass flow rate m = 0.004 kg/s, differential pressure p = 2068 kPa (300 psi), diameter d = 3mm; (◆) m = 0.010 kg/s, p = 5516 kPa (800 psi), d = 1 mm. Ambient backgroud sound pressure level (SPL) approximately 40 dB.

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