Protecting Ethylene Process Facilities: **A Review of Gas Detection Methods**

Europe accounts for nearly 20% of the global ethylene industry and it remains one of the largest markets. Currently two technologies are used to produce ethylene: one from a liquid raw material - naphtha derived from crude oil; and one from a gas raw material - ethane, which itself derives from natural gas – which includes shale gas. As ethane prices have decreased relative to that of naphtha within the last ten years, ethane-based ethylene production has risen. Because European shale gas reserves are not being developed, the West European petrochemicals industry produces 70% of its ethylene from naphtha.

Several ethylene detection technologies have the potential to mitigate consequences of gas leaks. Catalytic, point and open path infrared detection and ultrasonic gas leak detection are complementary methods that suit the complex circumstances surrounding ethylene production, transport and storage.

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Introduction

Few gases match the broad use of ethylene in modern society. Ethylene functions as starting material for industrial synthesis of linear polymers, aldehydes and other major chemical products. Plastics, plasticizers, surfactants, food additives, and fibers are products of this major building block. Today, the demand for ethylene is over 140 million tons per year with a growth rate of 3.5% per year, which ranks ethylene as the most widely produced organic compound globally.

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

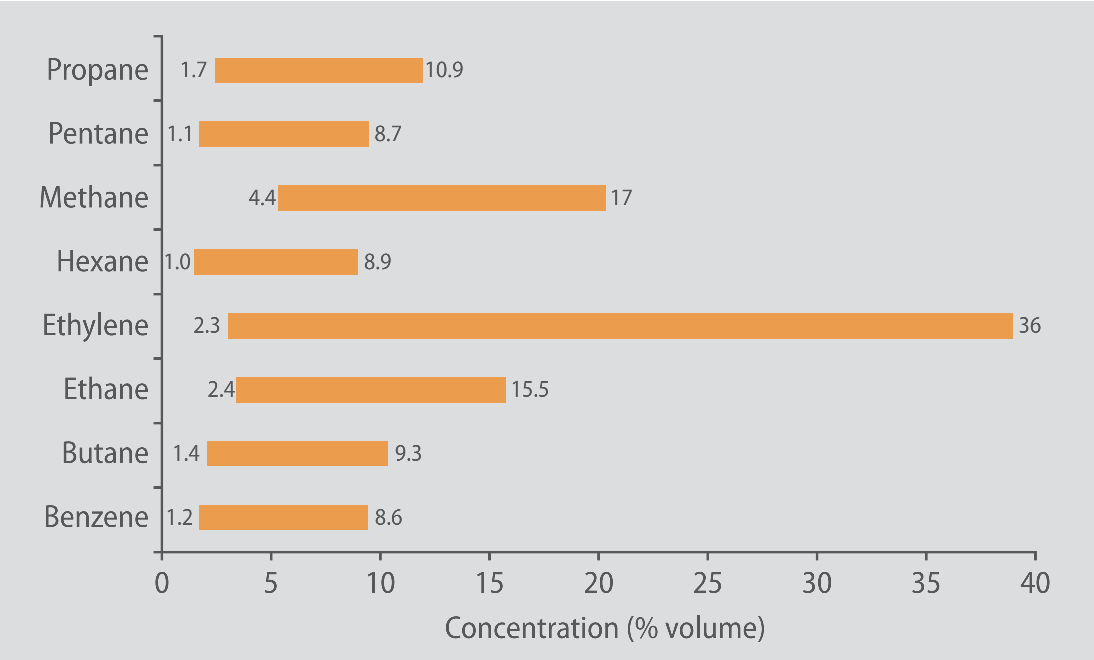

Figure 1: Explosive concentration ranges for select gases. LEL as defined by IEC 60079-20-1.

In addition, ethylene has among the lowest minimum ignition energies of industrial gases, a burning velocity that is approximately 35 to 60% greater than that of methane, and high flame temperature. Ethylene is considered to be a significant workplace hazard due to this combina-tion of physical properties. In the United Kingdom for example, ethylene is classified as a dangerous fluid as defined in Schedule 2, Pipeline Safety Regulations 1996 (PSR)[1].

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

Several detection techniques are available to monitor ethylene; infrared (IR) and catalytic detection are likely the most well-established. Others such as ultrasonic gas leak detection are emerging as comparative techniques.

Detection Technologies

Infrared gas detection—IR detection depends upon the ability of certain molecules to absorb light at wavelengths that are characteristic of molecular structure. Absorption characteristics are defined as 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 mm region.

Combustible IR instruments employ a dual wavelength technique. In order to prevent background distortions due to source aging, optical surface contamination 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 differential absorption technique, both active and reference channels are equally attenuated when contaminants are present within the IR beam (*Figure 2*).

Infrared combustible gas detection advantages are well known; infrared detectors can operate within oxygen-deficient or -enriched areas, are resistant to corrosion and are fail-safe. Failures such as beam block or defective light sources are revealed, enabling operators to restore devices 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 debris that may impair target gas access to the sampling chamber.

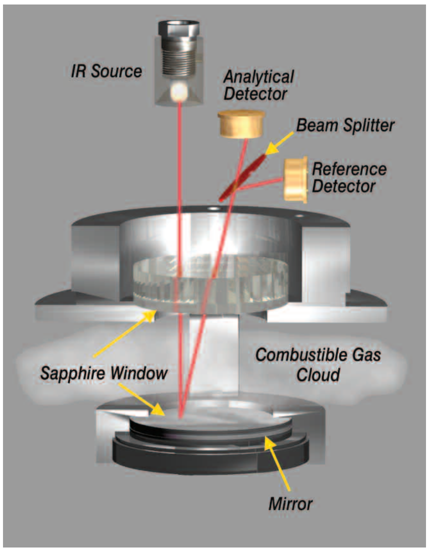

Figure 2: Typical point infrared short path operation

Infrared units configured for ethylene also function as non-selective, hydrocarbon detectors that show varied response to other hydrocarbons. Exposed to 10% 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 % LEL outputs at low concentrations on ethylene infrared units.

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

Combustible IR detectors can be of both point and open path types. 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 HVAC (heating, ventilation and air conditioning) systems. In contrast, an open path device uses an IR source coupled to a remotely-sited receiver (*Figure 3*). These devices can be used to measure ethylene along perimeters or across process areas when installed at defined spacing in one direction.

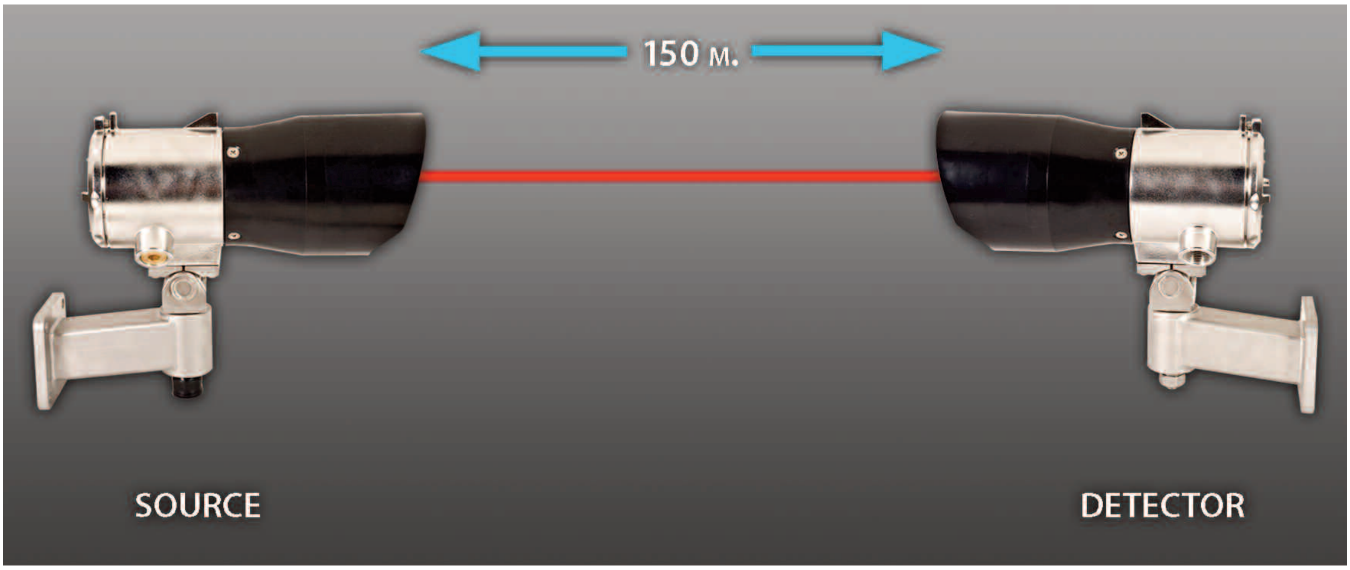

Figure 3: Typical open long path infrared operation

For ethylene monitoring applications, 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[2]. Degrees of confinement and obstruction are significant factors in flame front propagation and fire, or detonation's hazard potential. At distances of 1–9 m, depending upon congestion level, a combustible gas cloud will not produce flame speeds greater than 100 m/s or overpressures in excess of 150 mbar (2.2 psi), the threshold for major structural damage[3].

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).

Catalytic gas detection—A common technique for detecting ethylene presence is catalytic gas detection. Catalytic detectors employ catalytic combustion to measure combustible gases in air at fine concentrations. As combustible gas oxidizes in the presence of a catalyst, heat is produced; the sensor converts the temperature rise to a change in electrical resistance that is linearly proportional to gas concentration. A standard Wheatstone bridge circuit transforms the raw temperature change into a sensor signal (*Figure 4*).

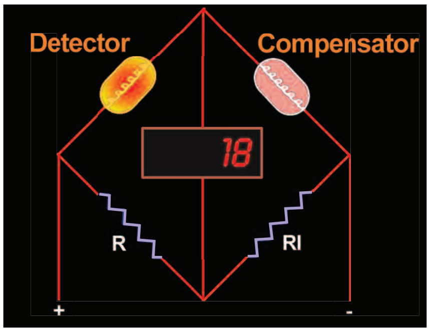

Figure 4: Typical catalytic bead sensor operation

Catalytic detector design simplicity belies several strengths that have made this detector type a mainstay of fire and gas safety applications for more than 50 years. Catalytic detectors are robust, economical, reliable, and self-compensating to environmental changes such as humidity, pressure and temperature. These detectors are also easy to install, calibrate and use. Once in place, detectors can operate for years with minimal maintenance, requiring only periodic gas calibration to verify operation. As catalytic combustion reaction is non-selective, catalytic detectors can be used to monitor for several target gases across many varied applications. Catalytic sensors are suitable to detect ethylene in concentrations well below the lower explosive limit.

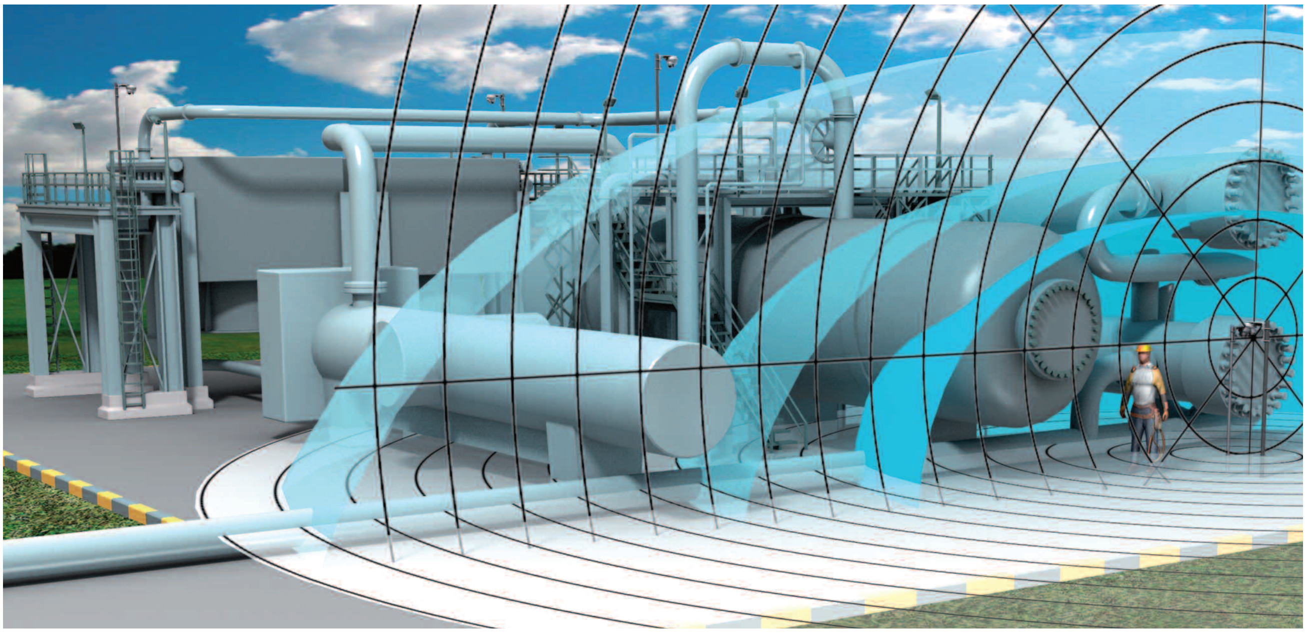

Figure 5: Typical ultrasonic detection coverage

Ultrasonic gas leak detection—Another non-selective ethylene detection method uses ultrasonic gas leak detection. Ultrasonic gas leak detectors respond to gas leaks by measuring changes in background noise; as gas escapes from a pressurized vessel, the gas emits broad-band sound, the ultrasonic component of which can be measured using a microphone. Detection coverage for high, low and very low noise levels is illustrated in Figure 5. Ultrasonic sound pressure level (SPL) is proportional to mass rate (leak rate) at a given distance and thus provides measure of the leak's severity. Leak rate in turn is mainly dependent upon leak size and gas pressure.

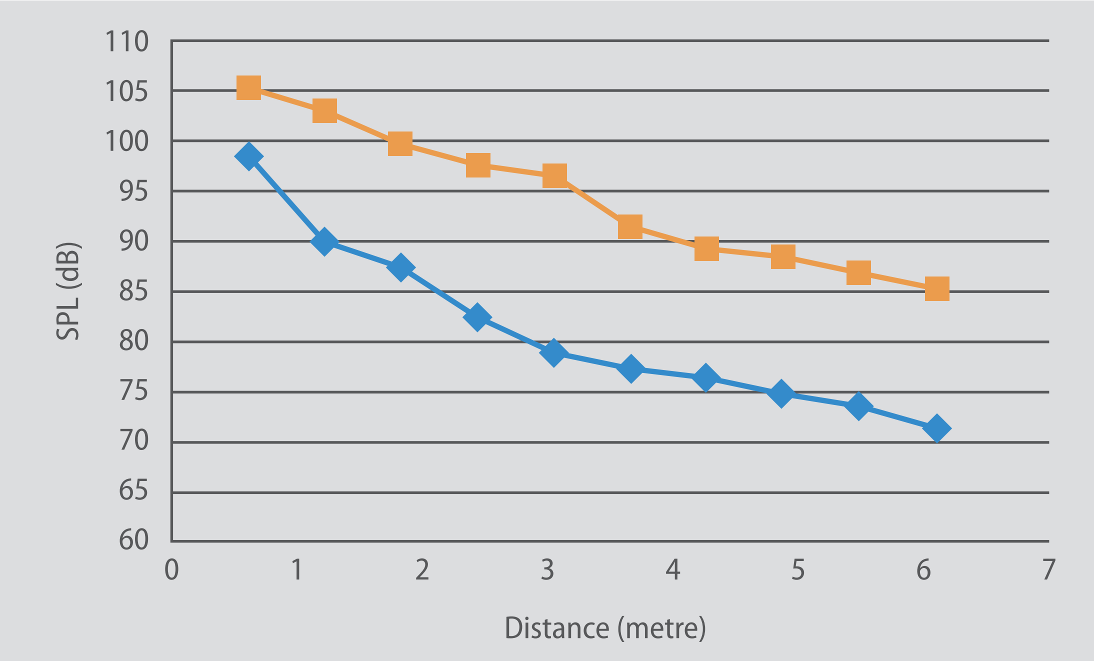

Figure 6: Sound pressure level (SPL) as a function of distance for ethylene leaks.
(♦) Mass flow rate m = 0.004 kg/s, differential pressure p = 2,068 kPa (300 psi), diameter d = 3 mm;
(■) m = 0.010 kg/s, p = 5,516 kPa (800 psi), d = 1 mm. Ambient background SPL ≈ 40 dB.

Advantages of ultrasonic gas leak detection include instant detection of pressurized gas leaks and immunity to changes in wind direction or gas dilution. Ultrasonic detectors provide broad area coverage and do not require transport of gas to sensor. Another advantage is that detector performance can be verified using live gas leaks during commissioning. Using inert gas, operators can conduct gas release simulations at a known leak rate and test detector response within potential locations.

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

Ultrasonic gas leak detectors respond well to ethylene. As shown in Figure 6, a gas leak detector can provide early warning of small leaks at distances of approximately 6 meters, affording wide area coverage in a variety of noise environments.

The Safety Company

Conclusion

As a key petroleum industry building block, ethylene is produced, stored and transported in quantities that few other industrial products can match. To provide for safe handling, chemical and petroleum companies must ensure failure prevention concerning pipeline, process and storage facilities that could potentially lead to gas release, 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 handling of this process fluid.

Infrared gas detection provides high integrity and reliability in point and open path configurations, essential methods for safety applications. As optical gas detection is a physical technique, high-target gas concentrations for prolonged periods and oxygen level changes do not degrade sensor performance. Most importantly, IR devices are fail-safe.

Simple in design and easy to manufacture, catalytic detectors respond to the greatest possible range of combustible gases including hydrogen, offer good repeatability and accuracy and fast response times. Due to their wide compass, they are used in fractionation sections where cracked gas in varying degrees of separation is present. These detectors are also installed inside of compressors or turbine enclosures with high temperatures. Such operations can be hot and will affect other sensor types, unless supplied with an air sampling system.

Unlike fixed point catalytic, point or open path IR detection intended primarily for detection of gas accumulations, ultrasonic gas leak detection responds to ultrasonic noise generated at the leak source itself, therefore providing the potential to compensate for limitations in effectiveness of traditional gas detection systems. Ultrasonic gas leak detectors can be installed in cracked gas compressors, turbines and distillation columns in cracking units and metering and pressure reducing stations in ethylene gas pipelines.

Acceptance of these ethylene monitoring techniques is currently gathering momentum as organizations assess gas release scenarios that might be present in ethylene production processes. None of these techniques, however, is a panacea, particularly over applicable temperature extremes for the most rigorous applications. The best strategy appears to be deployment of these techniques in combination, so that devices may cover a broader range of gas release scenarios while mitigating limitations. No doubt, where workforce and public safety require a high level of reliability and integrity, detection diversity has an important role to play in continuing efforts to improve process safety.

Location	Catalytic	Point IR	Open Path IR	Ultrasonic
MANIFOLDS	■	■	■	■
HEAT EXCHANGERS	■	■	■	■
GAS COMPRESSORS	■	■		■
TURBINE ENCLOSURES	■	■		■
PROCESS PUMPS	■	■	■	
METERING STATION/SKIDS	■	■		■
MARINE TERMINALS	■	■	■	

The table above shows typical use of catalytic, IR and ultrasonic gas leak detectors within select ethylene process locations.

References

[1] *The Pipeline Safety Regulations. 1996. London, UK: The National Archives. www.legislation.gov.uk/uksi/1996/825/contents/made, August 12, 2013.*
[2] *Dorofeev, S.B. 2006. A Flame Speed Correlation for Unconfined Gaseous Explosions. Process Safety Progress 26 (2): 140 -149.*
[3] *Dorofeev, S.B. 2007. Evaluation of Safety Distances Related to Unconfined Hydrogen Explosions. International Journal of Hydrogen Energy 32: 2118 – 2124.*

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