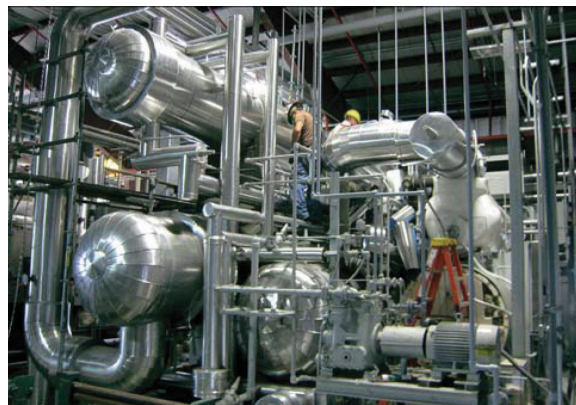# Detecting Toxic Gases with Open Path Systems

SPECTREX

Detecting Toxic Gases with Open Path Systems

Background

In February 2015, a Coca-Cola bottling plant in Speedway, Indianapolis initiated emergency procedures after a strong ammonia smell was sensed by 25 workers. The plant wasimmediately evacuated and a significant emergency response was provided by local Fire Department and Hazmat teams. The source of the leak was an 80,000 gallon tank, which was used in the refrigeration processes within the plant. Concentration readings fell from 700 ppm to about Photography courtesy of Piho Engineering 150 ppm, which was significant, though the plant could not be operated until they were further reduced to below 25 ppm. Throughout the incident, no threat was posed to anyone outside the plant, where readings were 2 ppm.

Photography courtesy of Piho Engineering

Another example of an industrial ammonia leak occurred in a frozen storage and logistics business in Shanghai, China in August, 2013 The chemical was used in food refrigeration involved in the importing, exporting, storage, and processing of seafood. A detached pipe cap caused a huge leak, as reported by the Shanghai Municipality Information Office, and led to the deaths of 15 people and injuring an additional 25.

In November 2014, a large amount of Hydrogen sulfide (H_2S) blanketed most parts of Moscow, Russia where emergency authorities directed everyone to stay indoors. It was later discovered that the gas had originated in a Moscow oil refinery but no injuries occurred.

In May 2014, an oilfield worker in the municipality of Hazelwood, in the province of Alberta, Canada was found unresponsive at one of the customer worksites. It appears that the worker died from exposure to high levels of H_2S.

While toxic gases may have many benefits and useful applications within a variety of industries, high concentrations can cause significant damage to humans and be life threatening.

Two particular examples of toxic gases commonly present in industrial and agricultural environments are ammonia and hydrogen sulfide. Ammonia is utilized in various industries in a wide range of processes, either as raw product or a byproduct. These include carbon capture and storage in the oil and gas industry, fertilizer, nitric acid, explosive, plastic production and more. Ammonia, NH_3, in gaseous form is a colorless gas with a characteristic smell.

However the gas is toxic and, even in liquid form when diluted, is extremely corrosive. Ammonia is toxic and can cause lung damage and death (see Table 1). It can also cause fires and subsequent explosions if concentration levels reach 150,000 ppm (15 percent volume). While it is essential to ensure concentration levels do not become extreme enough to cause a fire, it is equally crucial to ensure they do not reach life threatening levels. Therefore, ammonia must be neutralized if high levels are detected.

Table 1. The Effects of Ammonia at Increasing Concentrations

Ammonia	Increasing concentrations
25 ppm	TLV-TWA – Maximum exposure 8 hours
35 ppm	TLV-STEL – Maximum exposure 15 minutes
53 ppm	Detectable by humans
130 ppm	Irritates skin, eyes, nose, and respiratory tract
2500 ppm	Life threatening

Table 2. The Effects of H_2S at Increasing Concentrations

H_2S	Increasing concentrations
0.03 ppm	TLV-TWA – Maximum exposure 8 hours
4 ppm	Eye irritation
10 ppm	TLV-STEL – Maximum exposure 15 minutes
20 ppm	Severe nerve injury
30 ppm	Loss of smell, injury to blood brain barrier
100 ppm	Unconscious after 15 minutes, respiratory paralysis in 30–45 minutes
200 ppm	Serious eye injury and permanent damage to eye nerves
300 ppm	Loss of reasoning and balance
500 ppm	Unconscious in 3–5 minutes, asphyxia
700 ppm	Death - breathing will stop and death will result, permanent brain damage if rescued

H_2S is a toxic gas with a "rotten egg" odor that is colorless and produced by the anaerobic breakdown of organic material. It is a byproduct in many industries:

- Pulp and paper, produced by the breakdown of wood;
- Construction where it can be released during excavation work;
- Petroleum industry where H_2S is removed from natural gas and oil, and more

It can be used as a precursor to metal sulfides and has a number of uses within analytical chemistry. H_2S does not cause irritation at low concentrations but can be fatal at high concentrations (see Table 2). When burnt, H_2S releases sulfur dioxide, a very toxic and strong smelling gas that can cause irritation and death. At concentrations above 40,000 ppm (four percent), it may cause a fire or explosion.

Toxic gases have a broad range of uses, including agricultural fertilizer production, pure sulfur production, water purification, chemical reduction, oxidizing, toothpaste production, water repellent production, concrete sealant, and many more. While the gases are widely used in all these applications, it is important their concentrations do not reach dangerously high levels, risking those in surrounding areas. It is difficult to determine when a toxic gas is reaching dangerously high

concentrations. Even if it is possible to smell or use another sense to "detect" a toxic gas, this is unreliable because a lethal concentration may build up before anyone gets close to the leakage area. Additionally, because some toxic gases (e.g. H_2S) affect our sense of smell, it is very important they are detectable using reliable, accurate apparatus. To control the potentially dangerous effects of these toxic gases, they must be detected at low concentrations.

One method of detecting toxic gases is by "point" type detectors. These are typically semiconductor or electrochemical based detectors, in which the monitored gas reacts with the sensor. A grid of point detectors is required to monitor a large area, since the gas has to physically reach the sensor to be detected.

Toxic point gas detectors require periodic calibration and maintenance, which can be a considerable burden in large plants that may require hundreds of detectors. Since most detectors are installed in the highest risk areas, maintenance technicians are constantly exposed to hazardous environments and are often required to wear oxygen masks.

In many applications, a considerable improvement over point detectors is obtained using the method of open path, line of sight gas detection. Open path gas detection is based on a beam of light absorbed by the detected gas between a transmitter (source of light) and a receiver over distances up to 197 ft. (60 m). The chemical absorbs some of the beam's energy reducing the intensity of the beam. The received beam signal is used to determine whether or not a gas is present. This method can monitor even traces of gases as they "cross" the path between the transmitter and receiver units. As opposed to point type detectors, the toxic gas does not have to reach the receiver (detector) unit to be detected. This reduces the number of detectors required for a given area.

Open path gas detection (OPGD)

The theory of OPGD is based on the Beer-Lambert absorption equation, which is as follows:

I = Io x exp (-E x C x L)

Whereas:
- I is the intensity of radiation after passing through a gas cloud and is recorded as the output beam.
- Io is the intensity of radiation in a clean atmosphere.
- E is an absorption coefficient typical to the detected gas (dependent on the measured wavelength).
- C is the gas concentration in the measured cloud (in air).
- L is the length of the beam's optical path through that cloud.

The absorption coefficient E (as function of wavelength) is often called the chemical "spectral fingerprint" and is unique for each chemical substance. Oil and gas products have unique spectral fingerprints in the Ultraviolet (UV) and Infrared (IR) portions of the electromagnetic spectrum. An optical open path gas monitoring system analyzes these spectral fingerprints in several spectral bands where the monitored gases have defined unique spectral absorption lines. Specific filters are designed for each spectral channel to identify the gases.
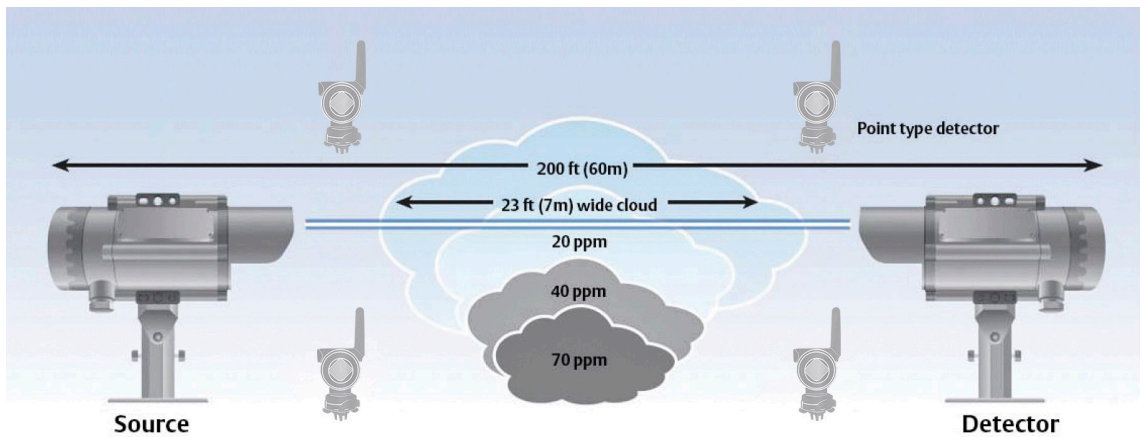
This scenario shows how the matrix of point type detectors can miss a leak or eventually only see diluted gas levels whereas an open path system will, in this case, measure 20 ppm x 23 ft (7 m) = 140 ppm x m...well above the 100 ppm x m alarm level.

100 ppm x m = a cloud of 100 ppm methane gas 3 ft (1m) wide 100 ppm x m = a cloud of 5 ppm methane gas 65 ft (20 m) wide.
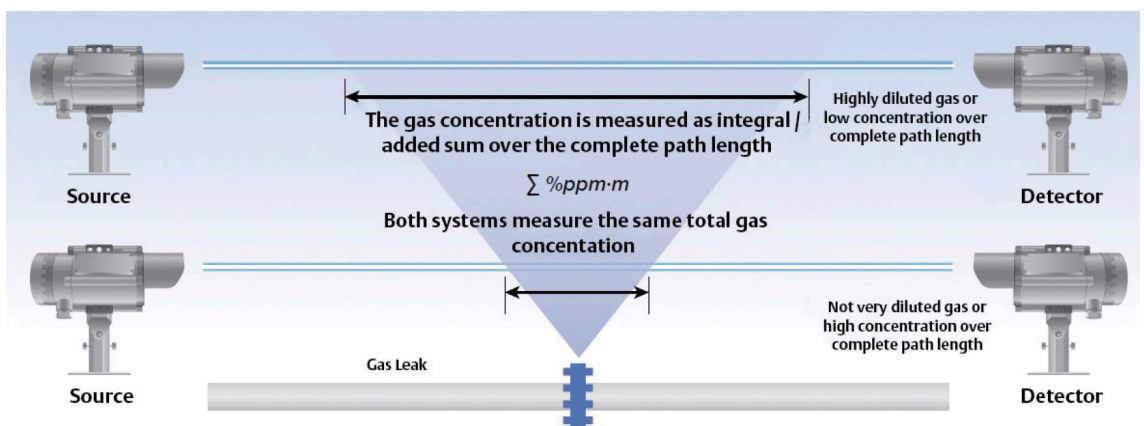
With reliability and safety being the most important issues when measuring and monitoring combustible or toxic gases, the following performance criteria must be addressed by the system:

- Reliable and fast detection – real time measurement and automatic self-testing
- Withstand harsh and extreme environments – humidity, rain, fog, snow, industrial chemicals, and background radiation (e.g. sun, lamps, heaters)
- Reliable false-alarm-free operation – immunity to any chemical reactions and to industrial and environmental radiation sources, which might cause false alarm or disable detection
- Low maintenance requirements – continuous operation without requiring manual testing and part replacement
- Easy alignment and commissioning – one-person setup

Recommended technology

Spectrex has developed a solution for the detection of toxic gases before their concentrations rise to a dangerous level. The Spectrex SafEye™ Quasar 950/960 Open Path Gas Detectors detect the following gases:

- SafEye 950 – hydrogen sulfide (H_2S)
- SafEye 960 – ammonia (NH_3)

The detector is able to detect H_2S/NH_3 at distances of up to 200 ft (60 m) using open path, line of sight technology. The system is fully operational and immune to false alarms caused by background radiation sources such as sunlight, filament lamps, projectors, heat generators, and other type of optical detectors.

The detector provides a warning signal when no longer able to provide accurate detection (e.g. the path is blocked or obscured). However, they can function effectively even when 90 percent of the light is obscured by extreme environmental interference such as fog, rain, or smog. An open path system consists of two parts: a light source (transmitter) and a detector (receiver) located at a predetermined distance. The transmitter is a unique flash lamp source, which can be activated at various frequencies and emits pulses of light with a wide spectral band (UV to IR). The receiver is the sensing and analyzing module of the system, which contains several sensors with unique filters.

The apparatus can detect different gases with respect to different bandpass filters. The location of the radiation source (transmitter) and receiver (detector) define the optical path.

The light source and detector are mounted and aligned at a predetermined distance (fixed in a given installation). The optical path to be monitored is the direct line of sight between them. Since the distance between light source and detector is different from one installation to the next, the gas concentration is measured in ppm x m (parts per million multiplied by meters). To obtain the average gas concentration over the optical path, the concentration is divided by the distance between light source and detector (in meters).

The transmitter, which can be activated at various frequencies, emits very short (microseconds long) high intensity pulses of light enabling the recognition of its unique pattern by the receiver, which distinguishes it from background radiation sources such as sunlight, filament lamps, projectors, and heat generators. The receiver contains several sensors according to the specific gases (or chemical families) to be detected. In the toxic gas models, the signal and reference wavelength bands are in the 0.2—0.3 microns UV range.

For more information on Spectrex's open path gas detectors, see
www.Spectrex.net/Applications/Industrial.

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