Developing Technologies to Detect Hydrogen Sulfide (H_2S) Gas

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Abstract

Hydrogen sulfide (H_2S) gas can cause nausea, headaches, unconsciousness, and death. Industries struggle to detect this deadly substance before it harms workers or communities. Safety system manufacturers have developed detectors that sense the H_2S quickly and accurately.

This paper illustrates, in general terms, considerations in effective placement of H_2S detectors: applications where the gas might exist and environmental conditions to think about. In addition, the paper reviews limits, strengths, and applications of the H_2S gas detection sensor technologies: electrochemical, metal oxide semiconductor (MOS), and optical.

Introduction

In high concentrations, hydrogen sulfide gas can cause unconsciousness and death very quickly. Still dangerous in lower concentrations, side effects of the gas include nausea, headaches, and skin and eye irritation. The oil and gas industry worldwide grapples with strategies to detect this deadly substance before it harms workers or communities. Safety system manufacturers strive toward the same goal by developing detectors that sense the H_2S quickly and accurately.

The primary function here is to save lives, so the speed of response is vital. The average person takes 12 breaths per minute, or one breath every five seconds. A solid detection plan is key to personnel survivability.

This paper covers the following topics:

- Health dangers posed by H_2S gas
- General guidelines for determining placement of H_2S detectors
- Conditions affecting gas-detector performance
- Fixed-detector technologies, existing and future, that effectively detect H_2S
- General characteristics of detectors

Deadliness of Hydrogen Sulfide

H_2S is a flammable gas that attacks the central nervous system. Although it is flammable, the toxicity of H_2S is so high that its flammable level is not reached before it begins to kill people. In addition, when used in areas of H_2S exposure, catalytic sensors (a standard in detecting flammable gases) life expectancy is reduced making them unreliable.

Trace amounts of H_2S are recognized by a distinctive odor of rotten eggs. Although the odor threshold of H_2S is very low, continued exposure results in an individual losing the ability to smell it.

According to the Occupational Safety & Health Administration (U.S. Department of Labor), the acceptable concentration limit for exposure to H2S is 20 ppm for an 8-hour period. The maximum peak exposure is 50 ppm for 10 minutes.

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Table 1 shows symptoms of exposure, which include eye and respiratory irritation, vomiting or nausea, convulsions, and coma or death.

TABLE 1: Physical symptoms of H_2S exposure over time

Exposure limits (ppm)	*Health Effects*
0.008-0.2	Olfactory threshold -"rotten eggs" smell detectable
20	Sense of smell to gas lost Concentrations tolerated for some hours without harm
20-50	Eye irritation
50	Prolonged exposure may cause pharyngitis and bronchitis
60	Prolonged exposure may cause conjunctivitis and eye pain
150+	Irritation of upper respiratory tract Sense of smell lost
250	Pulmonary oedema with risk of death
500	Very dangerous, evacuation should occur well below this level
1000	Loss of consciousness occurs
1000-2000	Acute intoxication: symptoms include rapid breathing, distress, nausea and vomiting. May be rapidly followed by loss of consciousness, coma, cessation of breathing.
2000+	Immediate loss of consciousness and high probability of death

Note: For further information, consult the IDLH Sheets from NIOSH.

H2S Locations and General Placement of Fixed Detectors

Acknowledging the importance of H_2S detection to life safety, one must consider the locations and the consequences of its presence.

A common byproduct of fuel development, sour gas (or H_2S) can be generated in a variety of ways. It is formed from the decomposition of organic matter and as a byproduct of various chemical reactions. And, for example, it can result from mixing a sulfide (such as sodium sulfide) and an acid.

The possibility of toxic H_2S levels exists in many industrial applications including farming, wastewater, stagnant cellars/sumps disposal, chemical, and, of course, oil and gas exploration and production. Specific to oil and gas production, these are some potential hazard areas:

- Drilling sites pose leak and blowout hazards.
- Consider gas detection near the driller stand, the shale shaker, and the bell nipple.
- Analyzer buildings take in gases to be analyzed. In these enclosed buildings, leaks of gases, which can include combustible, nitrogen, and H_2S, create dangerous hazards.
- Mud return line receiver tank
- Crude oil storage tanks, pipes, flanges, and valves require gas detection.
- Remote well sites require detection at the well heads, the storage tanks, and flare stacks.

In each situation, review drawings to analyze the probable sources of leaks. In addition, remember that H2S is heavier than air and will sink to the lowest lying area.

Most importantly, place detectors on HVAC air vents of accommodation buildings and personnel areas.

Consider assigning a team from the loss-prevention and project-management groups to survey the facility. They should decide the number and location of LEL and H_2S sensors. Typically, sensors will be placed next to potential release points. In addition, install sensors around the boundaries of each area to supplement the point detectors.

Environmental Conditions in the Area

Assess the conditions in the hazard area. Although no hard rules apply to best placement of H_2S gas detectors, several factors should be considered in determining the best sensor locations within the hazardous area.

The environmental setting of the application is the single most significant property that influences vapor dispersion characteristics and gas-detection capability. Wind direction, temperature and its fluctuation, and humidity with its changeability all affect the accuracy and response of detector.

Because H_2S gas is heavier than air, it will sink to low-lying areas. If the low-lying areas are confined, such as pits, trenches, and dikes, the risk is greater. In open areas, the gas will be taken and dispersed to a degree.

Fixed Gas Detector Technology Selection

The purpose of an H_2S detector is to save lives by warning personnel of excessive H_2S concentrations and initiating emergency procedures and precautions.

Because H_2S is flammable, one might consider using combustible gas detectors. That is not a good solution, however, because by the time the H_2S level rose to the level of combustion, the toxic air levels would be far exceeded, and people would die. H_2S kills at 1000ppm or 1/10th of the lowest explosive limit (LEL) measurements of the LEL scale.

Consider coordination among personal portable detectors, hand-held portables, and fixed gas detectors. Each facility should be equipped with an adequate number of personal portable sensors for operator use when they go out to plant areas. In addition, operators using a hand-held detector can check an area before issuing a hot-work permit.

Toxic detection technologies are advancing rapidly. Certain fixed-detector technologies are better suited to given situations than others. In general, electrochemical sensors and metal oxide semiconductor (MOS) sensors are the current proven detection technologies. Optical H_2S sensors are being developed.

Electrochemical detectors

Electrochemical detectors possess electrochemical cells that consist of electrodes enclosed in a case with a permeable membrane for diffusion of air into the cell. If H_2S is present in the air, an oxidation or reduction reaction occurs at one of the electrodes, and the current changes between the electrodes in such a way as to indicate a level of gas.

Today, certain gas detection systems are performance approved to a standard, such as the ISA standard. Look for performance approval on all gas detectors. This indicates the detector is fit for use and will do the job it’s supposed to.

Electrochemical sensors are highly sensitive and use very low power for operation (i.e., some models are available for intrinsically safe operation). They effectively target specific gases well and have direct linear output of current to gas concentration.

Though effective in detecting H_2S gas, electrochemical detectors are not resilient in high heat and prolonged low or high humidity conditions – for example, the electrolyte evaporates in arid conditions. The extreme conditions present in certain global locations make it difficult to use these technology types. The electrochemical detectors require frequent, routine calibration and do not fail to safe conditions (the sensor is unable to detect if it is not functioning properly). A non-functioning monitor is in itself a hazard.

Metal oxide semiconductor (MOS) detectors

An MOS device usually consists of a gas-sensitive resistive film, a platinum heater element, and an insulation medium. MOS sensors measure changes in electrical conductivity due to the presence of gas/vapor. With its long life and ability to operate in a wide temperature ranges, the MOS detectors are well suited to detect H_2S.

Although MOS sensors provide quick response, they can be sensitive to high humidity and must be frequently checked as the output tends to drift more than other technologies. Failure to regularly apply an H_2S sample gas to the MOS sensor may also result in the sensor “falling asleep,” in other words it may not respond as intended to a real H_2S leak. Recently, however, this sleep effect has been reduced by some detection manufacturers.

Other challenges for MOS detectors: They are affected by changes in oxygen levels. In addition, the detectors are not fail-safe, meaning the sensor is unable to detect if it is not functioning properly.

In recent years, device manufacturers have enhanced MOS sensors by adding nanotechnology (NT). NTMOS sensors have a similar look and operation as standard MOS sensors. When the nano-film is exposed to gas or vapor, the sensor electronically signifies the change in semiconductor resistance. This resistance change is non-linear, and the output can be electronically correlated to the gas concentration.

NTMOS has several benefits beyond standard MOS. It responds faster: T50 can be as quick as 5 seconds. The speed benefits arise because each nanotube’s total surface area is many times the surface area of its footprint. In addition, the NTMOS sensors do not go to sleep, as do some MOS sensors. Many devices can also be compensated for humidity, and therefore operate over a large temperature and humidity range.

Optical detectors

Optical detectors sense the absorption of light as it passes through gas. Both point and open-path optical detectors have the ability to perform valuable fault diagnostics. Because of the physics inherent in their design, optical detectors are not affected by temperature and humidity. Although the technology is available today, it is in the early stages and can be expensive.

Point-type gas detectors monitor a specific area or point within the facility and must be strategically located for early detection of gas. Point-type detectors must be routinely inspected to ensure they are capable of performing as expected.

The term open path indicates the open path between two sensors. Line-of-sight is another common term for this type of detector. The optical transmitter/receiver pair monitors the air within a beam of light projected between the two modules. Open-path gas detectors that monitor toxic gases (H_2S) are relatively new and performance is untried.

Where possible, combine technologies: point and open-path. To try to remove common mode failures, consider positioning the detectors with sources and multiple layers of protection through use of point and open-path fixed detectors.

Detector Characteristics

Detection of H_2S gas has come far in recent years. Certain detection characteristics are available and more are being developed.

- Speed of response must be considered as H_2S harms and kills very rapidly.
- The device must be trustworthy without false alarms or missed releases. Confident use of the devices comes from testing and a solid record of accomplishment. Third-party certification provides significant assistance in evaluating detectors.
- Safety availability should be considered, as a device that produces few faults is desirable. And for those few faults, a quick fix is a must.
- Calibration and maintenance costs can be lower with MOS and NTMOS technology.
- Accuracy of test gases and local vendor support represent significant issues as well.

Although important, characteristics of detector devices (strengths/weaknesses) are only part of the gas-detection design solution. The devices must be part of a larger system and should be supported by continuous maintenance of the facilities, frequent operator walkthroughs to identify any potential problem areas, and scheduled third-party safety compliance reviews and audits.

In addition, inspection cycles should be implemented by loss-prevention engineers and plant safety officers. Reports should be issued to plant management to correct any problem areas identified during these exercises.

Conclusions

Knowing the many dangers that H_2S gas poses to workers and communities, an effective gas detection plan is essential. Choosing the proper technology for the environment and conditions must be part of the overall plan.

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