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THE RIGHT TECHNOLOGIES FOR GAS LEAK DETECTION

Sourcing and implementing a suitable gas leak detection system is an important component of plant safety. This paper provides a number of solutions available to plant operators and the capabilities and limitations of the various gas detectors.

Protecting people and property is a top priority for every industrial plant, particularly the detection of hazardous gas leaks that can lead to significant damage and threaten personnel. However, for safety officers and plant managers trying to keep up with the evolution of detection technology, finding the optimum system to reduce risk is not a simple task, particularly since no single system or technology is the solution to every plant's problems.

Greatly reducing risk begins with the selection of the right gas detector for a given application and topology. Proper detector choice, in addition to correct placement and allocation, is critical for an effective gas detection system. Selecting the wrong gas detector, regardless of how reliable and suitable in number and detection coverage, may not offer early warning of a hazardous gas leak.

Conventional detector systems using traditional technologies such as catalytic, electrochemical and solid-state toxic gas detection continue to dominate most detection plans, yet new developments in sensor design and the emergence of new methodologies, including ultrasonic and open-path detection, suggest the need for a reevaluation. At the same time, the once promising technologies of solid-state combustible, thermal conductivity, and calorimetry gas detection are now used less often.

In fact, the requirements for gas detection technology have changed in recent years. Larger process facilities now often demand area monitors, which significantly reduce installation and maintenance costs per unit area covered. In addition, requirements for safety devices suited for safety integrity level (SIL) 1 and 2 environments have driven advances in diagnostics, which has promoted the use of optical gas detection instead of passive systems. Optical gas detection methods provide effective self-checks and actionable information on sensor degradation which allows for predictive maintenance. For these reasons and others, manufacturers should consider reevaluating how they select which sensor technologies they use in their hazardous gas detection plans.

Both catalytic and infrared (IR) technologies can detect combustible gases by diffusion and are suitable for a wide range of applications. IR instruments detect simple mixtures or a single type of hydrocarbon. These detectors are well suited for anaerobic processes, high concentrations of corrosive agents, and locations with a background of combustible gases because they are not affected by oxygen levels.

When monitoring hydrogen or hydrocarbon mixtures, it is better to use catalytic gas detectors. Catalytic gas detectors perform best in applications where typically the target gas would not be present. These detectors can only be used in applications where oxygen is continuously present since to operate they must have an oxygen gas concentration of more than 10 percent by volume.

In closed or congested areas, electrochemical and solid-state gas detectors are often used to monitor toxic gas leaks. In situations where the target gas is not typically present and in environments with relative humidity above 15 percent, electrochemical detectors are well-suited. These devices are sensitive to the target gases, have a true zero, and require little power. In applications with extremely high temperatures, low humidity, or stable ambient conditions, however, solid-state detectors are a good option. To monitor oxygen deficiency, electrochemical gas detectors installed near the breathing zone are ideal. In applications with open, uncongested spaces, open path gas detectors situated near infrared or ultraviolet detectors provide the widest coverage area per detector.

Ultrasonic gas leak detectors provide the fastest response when there is a pressurized gas release. This is particularly true in open, well ventilated areas where other detection methods may be ineffective. Air particle monitors work well in the detection of pressurized liquid releases. In addition to gas and ultrasonic gas leak detectors, operators can benefit from the deployment of air particle monitors. These instruments are designed to detect densities of oil droplets and other suspended particles in air, offering protection against pressurized liquid leaks. Common uses include the monitoring of gas turbine enclosures, engine rooms, heat exchangers, and lube oil systems. Air particle monitors are complementary to gas detection and when used in combination offer wide coverage for hazardous material releases.

A variety of challenging factors affect the performance of these technologies: location (indoors/outdoors); air flow; gas properties (type, density, buoyancy); environmental conditions like temperature and humidity; false alarm sources; and obstruction. Best practices for each application will be different, but it is critical to perform a proper process risk analysis in order to design a proper fire and gas system.

Options for Gas Detection

Catalytic and Electrocatalytic Detection

Detection systems include point detection, area monitoring, and perimeter monitoring. Catalytic detectors work by measuring the change in voltage produced from the catalytic combustion of the target gas in the sensor. When exposed to the gas, the material oxidizes in the presence of a catalyst, and as that happens, the heat of combustion increases the temperature, which in turn, increases sensor resistance. The offset voltage caused by the increased temperature is transformed into a sensor signal by a Wheatstone bridge circuit.

Catalytic detectors have many advantages despite their simple design. Catalytic detectors are robust, reliable, and economical as well as compensate for atmospheric factors such as temperature, humidity, and pressure. These detectors are also easy to install, calibrate, and use. In clean environments they will operate well for years with virtually no maintenance, only necessitating gas calibrations periodically for validation. Catalytic detectors are flexible and measure gas concentration of organic and inorganic gases including gas mixtures. In contrast, IR detectors cannot detect hydrogen and other inorganic gases.

However, catalytic gas detectors require oxygen to operate, which can be an issue. The catalytic process requires the oxidation of hydrocarbon gas, but oxygen levels can impact oxidation efficiency, and this can affect detection accuracy. The catalyst can also be poisoned or damaged by exposure to halogens, silicones, sulfur, or heavy metals. Furthermore, the sensor can be impaired by dust in the flame arrestor or from exposure to heavy oils and greases.

Electrochemical Detection

Electrochemical detectors are accurate, reliable, and respond quickly to toxic gases such as hydrogen sulfide, hydrogen chloride, and carbon monoxide. In electrochemical detectors, the target gas molecules react on the sensing electrode, generating a current. This current relates linearly to the amount of gas present.

While these detectors can detect a broad range of toxic gases and feature rapid response, high accuracy, and low power usage, they are also very sensitive to temperature and pressure, which can affect the chemical reaction. The reaction speed, a key advantage of this kind of detector, decreases as temperatures decrease. As a result, the temperature range of electrochemical cells is more limited than that of other detectors. It is not uncommon for these instruments to have low ambient temperature limits of -30 or -40°C.

Electrochemical Type Toxic Gas Detector

The pressure range capabilities are also restricted. Electrochemical cells have a pressure range of 10 percent of atmospheric pressure, and any pressure level outside of this range can lead to inaccurate gas measurements. Electrochemical detectors are also not failsafe and do not perform well over long periods in dry environments (with less than 15 percent relative humidity).

Solid-State Sensing

Solid-state sensors are made up of one or more metal oxides that are deposited as thin films onto an oxide substrate. The temperature of the film is increased by a heater circuit that heats it to an optimal point that produces the greatest sensitivity and fastest response time for gas detection. Biased electrodes embedded in the metal oxide measure the change in resistance, which is rendered into a gas concentration.

While it was previously thought that solid-state sensors offered several benefits, including a long life of up to 10 years and sensitivity to a broad range of gases, the technology has since been shown to be inferior in many applications. Solid-state sensors need to be exposed to the target gas, commonly hydrogen sulfide, periodically or otherwise are prone to desensitization. In addition, they are highly cross-sensitive and require a substantial amount of energy to operate. These limitations may not be apparent in the short term but will impact the detector's effectiveness over the long term.

IR Detection

Open-path IR detectors analyze atmospheric absorption in a region where the target gas absorbs and one where it does not absorb. The ratio between these absorption lines can provide accurate information of the gas concentration along an optical path. The reference sensor detects beam blockage, compensates for changing humidity and detects failed light source or dirty optics. IR detectors are largely unaffected by environmental factors like carbon dioxide, nitrogen, water vapor and oxygen. IR gas devices can be point or open-path detectors for hydrocarbon gas. In open-path IR devices, the IR beam can extend to more than 100 meters of sampling path, while point IR detectors extend to less than 10 centimeters.

Open-Path Gas Detector

All IR detectors are unaffected by poisons and offer high sensitivity, low maintenance, failsafe performance, and ease of installation. They also operate well in environments that do not have oxygen or that have enriched oxygen and can function in the continuous presence of gas. At the same time, though, IR detectors are limited to only being able to detect gases that are keenly absorbent within the IR spectrum. In addition, to detect gas, they need to have large sample volumes, so if a gas leak does not accumulate in the sample chamber, the IR device might not detect and respond to the leak. They also have a narrow range for ambient conditions, leading to higher maintenance requirements and expenses when exposed to high temperatures, high humidity, or dust, as these conditions could obscure the optics in harsh conditions.

Liquid petroleum gas spherical tanks are typically grouped in small clusters, often in rows. Since there are many possible sources of leaks, there is a likelihood that some sources of such releases are outside the coverage area of local detectors or close to the limits of local detection coverage. Open path infrared gas detectors can be used to monitor the perimeter of the tank farm or clusters providing high speed and accurate response to large combustible gas leaks. For perimeter monitoring, these detectors are placed along the bund walls rather than the property line. This should allow for the detection of smaller gas releases and provide more time to respond to such releases.

Ultrasonic Detection

Ultrasonic gas leak detectors "hear" the gas leak by using acoustic sensors to identify fluctuations in noise that is imperceptible to human hearing within a process environment. Gas releasing from a high-pressure vessel or other pressurized system generates ultrasound (sound frequencies too high to be audible to humans), which when detected by an acoustic sensor, provides a measure of leak rate. One important characteristic of sound is that

Ultrasonic Gas Leak Detector

density and pressure influence the propagation speed. Consequently, sound velocity varies with the medium, which is vital when detecting leaks.

Ultrasonic gas leak detectors have several advantages. They can detect a wide range of combustible, toxic or inert gases. They are ideal for windy environments since they have quick response times and they are not influenced by gas cloud dilution. These devices also have low maintenance requirements, no consumable parts and robust failsafe performance.

At the same time, however, ultrasonic gas leak detectors are unable to determine gas concentration and can only be used with pressurized systems. Pressure leaks below 2 bar or 30 pounds per square inch do not produce acoustic emissions at levels high enough to rise above the background noise in industrial environments (~50–80 decibels). In addition, they can only detect leaks produced by turbulent flow – therefore, the pressure behind the leak must be at least twice that on the other side for turbulent flow to occur. Vapors created from leaking liquids will not be detected by ultrasound technology even though the vapors might reach flammable or toxic points. Ultrasonic gas leak detectors are affected by manmade and natural sources of ultrasound. To avoid false signals from these sources, plants can increase the detection threshold or time delay, but this does risk diminishing sensitivity or response time.

Releases from pressurized gas wells are difficult to detect in open modules. Air currents can remove the gas far away from the leak source and from conventional gas detectors. Ultrasonic gas leak detectors provide rapid detection response time for pressurized gas leaks and are unaffected by air currents, the direction of the leak, and gas dilution. Because these devices are area monitors, they provide a powerful combination of detection efficiency and cost effectiveness for well pad production sites.

IR Gas Cloud Imaging

IR gas cloud technology was developed for military applications and offers some important advantages; however, in its current form it may be too expensive for general commercial use. An IR camera captures video imagery in an area that is illuminated by IR radiation either from a laser or from the sun and other natural sources. Any gas that is present in the space shows up in the video image as a collection of dark pixels, so gas leaks can be identified quickly by the dark cloud formed by the accumulation of pixels. It provides a wide field of view and long detection range. Some IR gas imagers can supervise entire sectors of a plant with detailed spatial resolution and can identify hazards in ways impossible with other detection technologies. Using IR cameras, plant personnel can examine the evolution of a gas cloud over time and determine the source or sources where the gas emanates from and the dispersal direction. However, IR imagers are not the best choice for detecting small fugitive leaks; also, their resolution can be negatively impacted by air current and humidity.

The Need for Integration

Safety systems that deploy a diverse range of detection technologies can counteract the serious impacts of gas leaks and potential for fire and explosions. A combination of ultrasonic gas leak detectors, fixed gas monitors and flame detectors is particularly effective because they are complementary and cover the three detection defense levels. The first stage is the immediate leak stage, which has the greatest opportunity for fast and effective mitigation; the second is the gas cloud formation or accumulation stage; and the third is the ignition stage.

Ultrasonic detectors are often installed outdoors to cover wide areas in challenging detection conditions. Ultrasonic gas leak detectors have a radial coverage of approximately 452 m^2 on 12-m radius.

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Point detectors, such as catalytic or electrocatalytic detectors, should be installed at or near known high-risk gas leakage points or accumulation areas to provide information on the level of gas present in these areas. They operate best at a monitoring radius of 0.5 to 2 meters, and are often placed near potential sources of gas leaks. Open-path gas detection systems are most effective at plant or process area boundaries. They monitor the plant perimeter and provide an indication of overall gas cloud movement in and out of the facility. The movement of gas clouds throughout the facility is tracked by monitoring the output signals of all the gas detectors within the safety system. Optical flame detectors monitor wide areas for IR or ultraviolet energy related to the ignition of a gas source and provide instant alarm condition back to notification and mitigation systems.

Clearly, choosing how to create a plan for the detection of hazardous gas is not a simple decision. Every technology has benefits and drawbacks and the most effective approach integrates a variety of options in different parts of the plant based on the specific needs of the application. Once the requirements are understood, plants can develop and implement an effective plantwide gas detection system.