Key Concepts in Gas Detection

Gas-detection systems are important front-line watch dogs, and provide many process plants with early notification of dangerous releases. Proper design and layout is critical to the functionality of these systems, but poses a challenge for many users since little standardized guidance is available. A qualified safety professional should be involved in all ultimate design decisions. When designing a gas-detection installation, the user must remember that gas detection is only one part of a facility's comprehensive safety management plan. To be most useful during facility operation, monitoring system users should address not only how many sensors are required and where they will go, but also how the real-time data provided by these devices can be used to improve the overall safety of the plant and its workers.

What is a Gas?

GAS - a substance that is normally in gaseous state at ordinary temperatures and pressures

VAPOR - a gaseous form of a substance that is liquid or solid at normal temperatures and pressures

FUME - airborne dispersion consisting of minute particles that come from heating a solid (often an oxide resulting from a chemical reaction between the particles and oxygen.

Types of gas and vapors

- Asphiyxiants - Cause suffocation by displacing O_2 (i.e. H_2, CO) or by interfering with blood's ability to carry O_2 (i.e. CO)
- Irritants/Corrosives - Cause inflammatory effect on tissue by chemical action (i.e. NH_3, Cl_2, O_3, SO_2)
- Toxic Agents - Poisonous to one or several organs (i.e. CS_2, AsH_3, CCl_4)
- Carcinogens - Cause Cancer (i.e. vinyl chloride)
- Central Nervous System Depressants - Cause disturbances to CNS (i.e. benzene, acetone)
- Combustibles - Liquids with flash point between 100°F and 200°F
- Flammables - Liquids with flash point under 100°F, gases that form flammable mixture with air at 13% by volume or less

Types of Gas Detectors

There are a number of methods used to detect the presence of various gas compounds. Typically, the most universally accepted methods are

- Electrochemical
- Catalytic bead
- Infrared
- Papertape

Electrochemical

Electrochemical gas sensors contain various components designed to react with a specific toxic gas; the reaction generates a current which is measured by the instrument and translated into a concentration value (PPM or PPB).

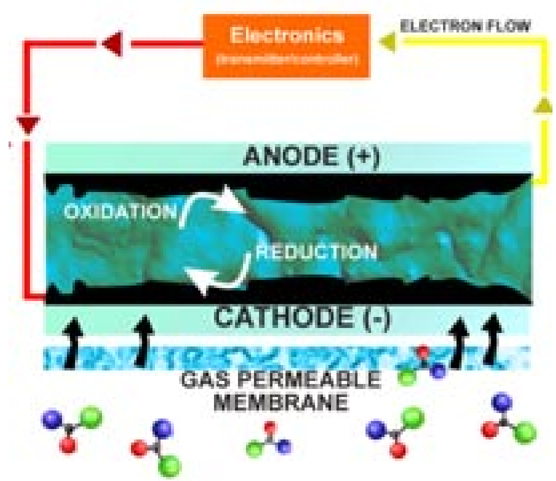

Figure 1 - Electrochemical Sensor

Catalytic Bead

Catalytic sensors "burn" combustible gases on a small extremely hot bead; the instrument measures the resulting increase in resistance and translates it into percent of lower explosive limit (LEL).Catalytic bead instruments are generally lower in cost

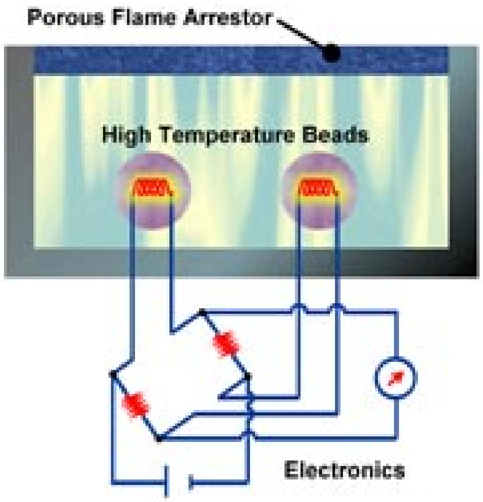

Figure 2 - Catalytic Bead Sensor

Infrared

Infra-red instruments shine a "tuned" beam of light through the gas sample. If the target gas is present, a portion of the beams light spectrum is abosorbed in proportion to the concentration of the gas. Infrared-based instruments are generally more expensive to purchase but provide lower, long-term cost of ownership as they require less maintenance do not require span calibration.

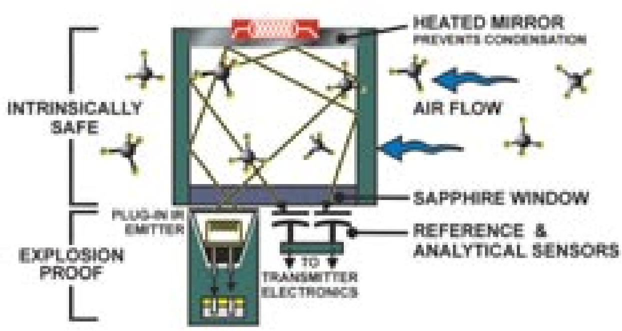

Figure 3 - Infrared Sensor

Papertape

Paper tape instruments use chemically-impregnated tape to very accurate and specific detection of toxic gases. Much like a piece of litmus paper, the tape changes color when exposed to a given gas; the color change is detected by a photocell, analyzed, and translated into a concentration value. Papertape instruments are not offered in this price guide, however are offered in Scott/Bacharach's GMD Systems Price Guide.

Understand the application

Before purchasing a detection system, the user must decide which gases the system should monitor. Legal requirements provide a good starting point for making this decision. Local and federal regulations, fire and building codes, and industry safety standards specify the use of gas detectors in certain types of facilities and for certain types of toxic and combustible gases.

The local fire Marshall or a qualified safety engineer should be able to provide system designers with a comprehensive list of applicable regulations, codes and standards. Unfortunately, regulations, standards and codes only cover a small percentage of all applications in need of gas monitoring. In most cases, other criteria must also be used to decide which gases and equipment components to monitor. The most important consideration is the actual hazard posed by the gases. These hazards are driven by toxicity or explosion risk.

Since some toxic gases are more dangerous than others, engineers deciding what to monitor should evaluate the absolute toxicity of substances, based on factors such as LC 50 (the median lethal concentration), short-term exposure limit (STEL), ceiling limit (the concentration that should not be exceeded), and IDLH (the concentration immediately dangerous to life and health). These factors are available from a variety of organizations, such as the U.S. Occupational Safety and Health Admin.(OSHA; Washington, D.C.), American Conference of Governmental Industrial Hygienists (ACGIH; Cincinnati, Ohio) and National Inst. for Occupational Safety and Health (NIOSH; Cincinnati, Ohio) [2].

The primary hazard associated with handling flammable or combustible gases is the risk of explosion that could result from a leak or spill. As a rule of thumb, the lower the flashpoint or lower explosive limit (LEL) of a gas, the more important it is to monitor.

System users should install monitoring devices to detect leaks of any combustible and flammable substances whose flashpoint is below ambient temperatures, since these substances immediately give off vapors, which may be sufficient to form an ignitable mixture. Note that certain combustible gases are also toxic, with permissible exposure limits under their LELs.

Methanol, for example, has an STEL of about 250 ppm – well below its 6% (or 60,000-ppm) LEL. In areas where a leak could result in personnel exposure, these gases should generally be evaluated primarily as toxic hazards, rather than as explosion hazards. In some cases, even non-flammable or non-toxic gases (such as nitrogen) should be monitored. This is especially true when the potential exists for that gas to leak into an enclosed area. Such leakage would increase the risk of oxygen deficiency, which puts workers at risk of asphyxiation.

Identify Potential Danger Points

Site-specific danger points can be divided into two broad categories:

• ***Release points.*** Locations from which hazardous gas could be released.

• ***Receptor points.*** Locations where hazardous gases could pose a threat to personnel, property or equipment.

In the case of flammable or combustible gases, the receptor point is specifically an ignition source – with no ignition, there is no threat to personnel, property, or equipment, except possibly through oxygen deprivation. In theory, all vessels, pipes and pieces of equipment containing hazardous substances, as well as all areas around these items, are potential danger points. In practice, however, it is generally prudent to focus on a smaller number of specific danger points to balance monitoring needs with capital and on- going maintenance costs. While most facilities have numerous release and receptor points, it is important to recognize that these two categories of dangers are not always located at the same site.

Release Points

To identify specific release points, the users should review all hazardous-area-classification drawings, which provide useful information on flammable- and combustible-gas danger points (e.g., they will indicate Class 1 areas, as defined by the National Electrical Code). Process-safety-management and risk-management plans can provide similar information for toxic gases handled onsite. Additional gas-release points and areas of potential gas buildup can be identified using process-and-instrumentation diagrams (P&IDs). Using such documents, the user should carefully evaluate the facility's gas-storage and inventory areas, as well as distribution, processing, ventilation, and waste/gas-treatment systems. Any transportation routes where gas or high-vapor-pressure liquids are transported (in trucks, railcars, cylinders and so on) should also be included in this evaluation.

In general, gas detectors used to monitor potential release points should be positioned close to the potential leak point, with consideration given to the likely mode of release. Common release points in process facilities include:

• Seals and flanges for pumps and compressors

• Valve-stem seals

• Expansion joints

• Gaskets

• Compression fittings

• Weld failures

• Loading and unloading areas

• Liquid- and gas-storage areas

• Sample points

• Battery rooms

• Runoff areas (such as sumps, oily water sewers and wastewater-treatment areas)

• Piping-distribution manifolds (such as valve-manifold boxes)

It is also a good idea to monitor certain locations where there is high potential for damage or injury to personnel – even if no specific release point exists nearby. These locations include areas where gases could potentially build up (e.g., cable vaults), as well as any areas where highly toxic or highly flammable combustible gases are stored, handled, transported or processed.

Receptor Points

Identifying receptor points should begin with a review of the facility's layout or floor plan, noting areas where personnel are likely to circulate or congregate on a regular basis (including evacuation and exit routes). P&IDs, as well as the plant's process-safety-management plan, can help determine potential ignition points. Gas detectors used to monitor receptor points should be positioned between release and receptor points. Common receptor points include:

- Analyzer shelters
- Facilities where plant personnel could be present
- Switchgear shelters
- Internal combustion engine shelters
- Confined spaces
- Nearby communities and facilities
- Facility-air intakes are also common locations for detectors monitoring receptor points in plants.

Determine Gas Characteristics

Vapor density is a key criterion in positioning gas sensors. Heavier-than-air gases, including vapors from high vapor pressure liquids, tend to sink and flow in thermal layers along the ground, and will often accumulate in low places such as pits or ditches. Since they collect easily and are less likely to disperse, more sensors should be used to monitor these substances in unenclosed areas, compared with lighter-than- air gases.

Sensors for heavier-than-air compounds, such as hydrogen sulfide, should be located near ground level – typically about 18-24 in. above the ground – or in low-lying areas where the gas may gather. In contrast, sensors for lighter-than- air gases should generally be located above the danger point.

In enclosed facilities, it is typical to mount sensors for low-vapor-density gases on the ceiling. Sensors for gases with the same density as air should generally be located at or near breathing level. Note that when monitoring for oxygen deficiency, one should consider the density of the gas(es) that are displacing the oxygen. For example, in a helium cylinder storage room, the first indication of a leak will be seen by an oxygen sensor mounted close to the ceiling (helium will rise and “crowd-out” the oxygen near the ceiling).

Gas release temperature should not be ignored when evaluating vapor density. Liquefied, lighter-than-air gases, such as LNG, will generally behave like heavier-than-air gases immediately after a spill, but will soon begin to rise as the vapors become diluted and warm up to ambient temperatures. Similarly, some heated heavier-than-air gases, such as hydrogen sulfide, rise when first released, but will settle as they cool and their density increases above that of air.

It is important to recognize that factors such as ventilation and air currents, especially for gases whose densities are similar to air, may alter these general recommendations. Strong air- flow through a room, for example, may make an exhaust duct a better location than the ceiling for monitoring a lighter-than-air gas.

Mode of storage and release can also affect the monitoring setup suggested by vapor density. Liquefied gases and high-vapor-pressure liquids are typically released as liquid spills (or jets) that subsequently evaporate. The rate of evaporation varies positively with the surface area of the liquid pool (which is reduced by dikes or embankments), the boiling point or vapor pressure of the liquid, and the heat transferred from the ground and atmosphere.

In general, the slower the rate of evaporation or the denser the vapor, the more important it is to place sensors close to the location where the liquid accumulates. Meanwhile, prevailing air or ventilation currents become more important considerations as the rate of evaporation increases.

Gases stored or transported under, pressure are released as a gas (or two- phase, liquid-gas) jet. If a jet’s release point or direction is predictable – for example, in a gas cabinet or by a valve where hoods or cones are used to direct the jet – it is generally desirable to place a detector in its path. Otherwise, detectors should be placed either in multiple locations around the danger point or in areas where the gas is likely to travel or settle after being released (taking into consideration prevailing air or ventilation currents).

Note that lighter-than-air gases will often sink immediately after release due to the presence of aerosols in the jet, and the drop in temperature that accompanies a drop in gas pressure. Most gas jets experience substantial mixing, and, in the open can disperse below dangerous levels a short distance from the leak point. However, prolonged leaks and re- leases in confined or semi-confined areas still pose substantial threats.

Indoor vs Outdoor Detection

Although indoor releases are often much more dangerous than outdoor ones – due to confinement or finite volume available for diffusion – their behavior is also more predictable. Studies have shown that in unexhausted rooms, gas tends to reach uniform concentration above (or below) the leak source very rapidly. The more mixing that takes place through convection currents, ventilation and so on, the more quickly the gas will reach a uniform concentration.

In this application, ”typical” sensor locations – those based primarily on vapor density and release mode) – can be used. Note that when very hot air exists near the ceiling, some thermal stratification may occur.

For instance, warmer, lower-density air may slow the passage of a gas to the roof. Since most indoor process facilities are exhausted, the effect of mechanical ventilation is important to consider.

Where ventilation rates are fairly rapid sensors often provide the best indications of air conditions in the room, chamber or cabinet. Note that in some cases, sensors may have to be mounted in several ducts, since code requirements require ventilation-system design to take gas density into account. For example, where mixtures of light and heavy gases exist, ventilation must capture gas at both high and low points.

In situations where ventilation rates are slower, a smoke study should be per- formed to confirm that the sensor will ”see” a gas leak. In such a study, a puff of smoke or some other easy-to-see fume is released, and its behavior in the prevailing air currents is observed. If ventilation ducts are interconnected and a potential release point lies ”upstream,” or if air is drawn from the outside near a potential leak source, it may also be desirable to locate a sensor at or near the air-inflow duct. In certain cases, such as when highly toxic gases are being handled, it can be useful to monitor breathing zone locations as well, for added safety.

Monitoring outdoor gas releases is significantly more complex, as gas behavior is impacted by many more variables. Meteorological conditions must be considered because gas disperses most rapidly during sunny afternoons with light wind, and least rapidly during clear nights with light wind.

It is important to note that predicted release behavior can be significantly altered by topographical characteristics created by buildings, process vessels, piping arrays and so on, since most dispersion models assume flat surfaces.

Installing a Gas Detector Quick List

Prior to installing a gas transmitter, consideration should be given to the following items when choosing its location:

1. ***Orientation*** - Always mount the sensor pointing downwards.

2. ***Gas Density*** - For gases heavier than air, it is recommended that the sensor be installed approximately 18" from floor level. In these applications care should be taken to protect the sensors from physical damage. For gases that are lighter than air, sensors should be installed at a high level or close to the potential leak source.

3. ***Potential Gas Sources*** - The location and nature of potential vapor/gas sources (e.g., pressure, amount, source, temperature, and distance) need to be assessed.

4. ***Ambient Temperature*** - Insure that the system is located within an area that complies with the specified operating temperature range.

5. ***Vibration*** - Mount the transmitter and sensor in a manner that minimizes vibration.

6. ***Accessibility*** - When determining mounting location, consider future maintenance and calibration requirements.

7. Avoid *water.* Droplets adhering to the outer membrane of the sensor will reduce or negate sensor performance. A rain shield is recommended for outdoor installations.

8. ***Avoid strong electromagnetic fields***. Mounting the gas transmitter near power transformers or other strong EM fields may cause undesirable results.

9. Avoid pressure and excessive air velocity. GasPlus sensors are designed to measure gas concentration under normal atmospheric conditions with up to 1 LPM air flow. High air velocities will result in inaccurate measurement and reduce sensor life.

10. Conduit Seals. Protect the transmitter electronics from moisture by thoroughly sealing the conduit entries and tightening the cover of the transmitter housing.

11. Distance. All systems that separate the gas sensor (or transmitter) from the main controller electronics have have distance limit specifications. Ensure that the application’s distance requirements are within specifications and that the appropriate gauge wiring is used.