GAS AND VAPOR DETECTORS AND ANALYSIS SYSTEMS

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1.0 SCOPE

This data sheet provides guidance on the installation and maintenance of gas detection systems. For the purpose of this data sheet, “gas” and “vapor” are considered to be interchangeable terms. Refer to the appropriate occupancy-specific data sheet for recommendations and guidance on integrating these devices with process control systems and other alarm systems. Refer to FM Property Loss Prevention Data Sheet 5-48, *Automatic Fire Detection*, for more information about gas-sensing fire detectors.

1.1 Hazard

Reliable gas detection systems are critical to safe operation of many processes. A lack of gas detection or its poor design can lead to fire and explosion where flammable concentrations were not detected (or were not detected in a timely manner).

1.2 Changes

October 2018. The document has been completely revised. Major changes include the following:

A. Added explanatory text to the scope regarding the equivalency of gas and vapor terminology. Deleted references to vapor detection throughout the document.

B. Added a recommendation for two independent power supplies, with automatic switchover.

C. Added a recommendation for audible and visual alarms in the vicinity of the detector, and at a remote, attended location.

D. Added recommendations for commissioning, calibration, and maintenance.

E. Added support information for locating detectors.

F. Added a new appendix providing an overview of current gas detection technologies.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

2.1.1 Use FM Approved equipment, materials, and services whenever they are applicable and available. For a list of products and services that are FM Approved, see the *Approval Guide*, an online resource of FM Approvals.

2.2 Construction and Location

2.2.1 Installation and Location

2.2.1.1 Provide detectors suitable for the gas being detected and the process environment, including temperature range, electrical classification, corrosiveness, etc.

2.2.1.2 Install gas detection systems in accordance with manufacturer’s instructions.

2.2.1.3 Locate gas detectors to ensure timely detection of release or as required in ductwork. Consider physical characteristics of the gas being detected, potential leak sources, and airflow patterns. See Section 3.1 for additional information.

2.2.2 Power Supplies

2.2.2.1 Provide all gas detection systems with a minimum of two reliable and independent power supplies.

2.2.2.2 Size the primary power supply to supply the maximum normal load of the gas detection system. Arrange the secondary power supply to automatically switch over the power supply within 10 seconds and without loss of signals. The secondary power supply keeps the equipment operating when a primary power supply fails.

2.2.2.3 Size the standby (secondary) power supply to provide necessary power for a minimum of 24 hours. The installer should provide completed battery calculations to ensure standby power requirements are met.

2.2.2.4 Install one of the following as the secondary power supply:

A. Storage batteries only

B. An uninterruptable power supply (UPS)

C. Reliable onsite emergency power supply, such as an automatic-switchover generator

2.2.2.5 Locate and protect wiring, cables, and tubing to avoid mechanical damage. In vulnerable locations, install tubing in conduit or equivalent. Conduit is not needed for short lengths of cables or tubing near detectors and controls.

2.3 Equipment and Processes

2.3.1 Alarms and Supervisory Devices

2.3.1.1 Arrange the gas detection system to activate audible and visual alarms in the vicinity of the gas detector system and at a physically separate location outside of the process area.

2.3.1.2 Arrange the alarm to be reset manually after the amount of gas has returned to an acceptable level.

2.3.1.3 Ensure appropriate action is taken in response to the alarm. See the occupancy-specific data sheet for additional recommendations for responses to gas detection system alarms.

2.3.1.4 Supervise and arrange the gas detection system and circuits to alarm upon loss of power or loss of sampling airflow. Provide trouble alarms that are distinctive from operation alarms transmitted to a physically separate location from the process area.

2.4 Operation and Maintenance

2.4.1 Commissioning

2.4.1.1 Test gas detection systems following installation to ensure proper operation and signal transmission.

2.4.1.2 Where multiple detectors are installed, identify each detector as to function, area controlled, and operating instructions.

2.4.1.3 Verify the gas detection system is calibrated to the intended operating range and alarm thresholds.

2.4.2 Impairment

2.4.2.1 Establish a procedure for taking the gas detection system out of service for repair or maintenance. The procedure should include, at a minimum, documentation on taking the system out of service, notifying personnel, and placing the system back into service. Procedures should also include shutting down processes until the detector system is restored or providing other supervisory equipment (such as portable gas detectors) in the process area if shutting down is impractical.

2.4.2.2 Restore the gas detection system as soon as practical following an outage for maintenance or repair.

2.4.3 Calibration and Maintenance

2.4.3.1 Have gas detection systems calibrated by qualified personnel on a routine basis, and document all calibration tests. Base the interval between calibrations on manufacturers' recommendations or the appropriate occupancy-specific data sheet, whichever interval is shorter.

2.4.3.2 Have qualified personnel perform regular maintenance in accordance with manufacturer's instructions or as determined necessary by experience derived from the operation of the detector and the associated equipment. At a minimum, do the following:

A. Check the operation of any controls and alarms at the designated set point.

B. Check the electrical connections and electronics at detectors (remote), and for the controls and alarms.

C. Check sample lines for leaks, obstructed filters and flame arrestors, proper flow, and condensate.

D. Check primary and secondary power supplies (batteries) for adequate power and reliability.

2.4.3.3 Maintain records of periodic performance calibration and maintenance operations. Have records reviewed by supervisory personnel knowledgeable in the operation of the gas detection system and authorized to take corrective action as appropriate.

2.5 Training

2.5.1 Train personnel to recognize alarms and take appropriate action for the process and equipment involved. See Data Sheet 10-8, *Operators*, and the appropriate occupancy-specific data sheet for more information on recommended actions to take following a gas detection alarm.

2.5.2 Train personnel responsible for calibration and maintenance in the proper operation and specific function of the detectors and the associated system.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Location of Detectors

There are several documents that provide qualitative guidance on the number and location of gas detectors in process areas (such as EN 60079, Part 29-16-1, *Explosive Atmospheres: Gas Detectors*), performance requirements of detectors for flammable gases (ISA TR84.00.07, Guidance on the Evaluation of Fire and Gas System Effectiveness), and the CCPS publication *Continuous Monitoring for Hazardous Material Releases*. These documents provide guidance on the most common approaches to gas detector placement, including target gas cloud and scenario-based monitoring.

Placement of gas detectors is usually determined by three factors: physical characteristics of the target gas; airflow patterns; and the likely location of leaks.

The physical characteristics of the gas, such as specific gravity, are used to identify the height at which a detector should be installed. Detectors targeting gas with specific gravity greater than 1.0 (heavier than air) may be placed below the level of the expected leak. Similarly, detectors targeting gas with specific gravity less than 1.0 (lighter than air) may be placed above the level of the expected leak. In addition, placement should be based on the physical characteristics of the gas at the process conditions. Butane, for example, is normally heavier than air, but can be used in processes at high temperature and/or pressure that impacts its buoyancy characteristics.

The role of airflow, particularly in “open” process areas and outdoor areas, will greatly impact the location of detectors. In indoor “open” process areas, the airflow patterns will be determined by the mechanical ventilation system. In outdoor areas, the prevailing natural air currents should be considered to identify the optimal location of gas detectors. For critical process applications, where data is available, “wind roses” may be developed to provide a robust analysis tool. Wind roses are graphical charts presented in a circular format that characterize the speed and direction of winds at a location.

Finally, the process equipment and piping should be analyzed to identify any areas where leaks are relatively likely to occur, such as valves, gauges, flanges, T-joints, filling or draining connections, etc.

Placement of detectors at a process facility should be determined by analysis and documented, even if the analysis results in a simple grid pattern, or a single detector in a critical area. It is important to understand how detector placement was arrived at so it can be reviewed as part of any management of change program.

The data established above can be used in the development of a gas detection system using several methods. A “volumetric” approach can be used that identifies a spherical gas cloud, and detectors placed in a regular or staggered grid pattern at intervals likely to provide timely detection of the target cloud. The size of the target cloud is associated with the flammability or toxicity characteristics of the target gas and the blockage ratio (confinement) of the cloud.

Another common methodology is the Minimum Distance to Source Problem (MDSP). This method involves placing detectors close to potential leak sources with the assumption that such placement will provide the most effective response. An analysis of MDSP should address the location relative to the development of a vapor cloud, possibly determining a separation distance from high-pressure equipment. Otherwise any leak of gas is likely to pass by in a high-speed jet and not be detected.

The most sophisticated of the commonly-used methods for detector placement is the scenario coverage approach, which uses gas dispersion scenarios as well as standards, regulations, and cost-benefit analysis to determine the optimal number and location of detectors for a process area. There are several subsets of the scenario coverage approach, all of which have pros and cons depending on the goals and details of the facility.

4.0 REFERENCES

4.1 FM

Data Sheet 10-8, *Operators*
Data Sheet 5-48, *Automatic Fire Detection*

APPENDIX A GLOSSARY OF TERMS

FM Approved: Products and services that have satisfied the criteria for FM Approval. Refer to the *Approval Guide*, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

APPENDIX B DOCUMENT REVISION HISTORY

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APPENDIX C SUPPLEMENTARY INFORMATION

C.1 Gas Detector Overview

A gas detector is a device that detects the presence of various gases within an area, usually as part of a system to warn about gases that might be harmful to humans or animals. Some of the ways that gas detection safeguards life and property include the following:

- Providing early warning of hazardous conditions
- Providing an opportunity for evacuation
- Triggering alarms and recording events
- Providing time for intervention and correction
- Triggering facility protection systems such as ventilation, water mist, and fire suppression

Other purposes of gas detection include the following:

- Satisfying local fire codes and insurance companies
- Addressing real and perceived safety concerns
- Complying with codes, standards, and regulations (laws)
- Monitoring combustible and toxic gases plus oxygen

C.1.1 Toxic Gases

Many toxic gases have known health hazards. Some toxic gases are also flammable, but are toxic at levels far below their lower flammable limit (LFL). Therefore, toxic gas monitors are fundamentally different from LFL monitors. Within the field of toxic gases there are many commonly used abbreviations, including the following:

- **TLV:** Threshold limit values (TLVs) are meant to be used for the protection of people who may be exposed to toxic gases in the workplace. Exposure at or below the level of the TLV does not create an unreasonable risk of disease or injury.

- **TWA:** The time weighted average (TWA) is a measure of the average exposure for an 8-hour workday and 40-hour workweek. The 8-hour TWA PEL is the level of exposure established as the highest level of exposure an employee may be exposed to without incurring the risk of adverse health effects.
- **PEL:** Health and Safety officials, such as OSHA in the United States, set enforceable permissible exposure limits (PELs) to protect workers against the health effects of exposure to hazardous substances. PELs are regulatory limits on the amount or concentration of a substance in the air. They may also contain a skin designation.
- **STEL:** Short-term exposure limit (STEL) is defined as a 15-minute TWA not to be exceeded at any time during the workday. Some agencies require a minimum of one hour between exposures and a maximum of four exposures per day.
- **PPM:** Parts per million (ppm) is the most common unit of measurement for toxic gases. Most toxic gases are hazardous at low levels; because of this, toxic gas monitors measure concentration ppm. However, detectors could also measure in parts per billion or percent by volume in air.

C.1.2 Flammable Gas Detectors

Flammable gas detectors are also known as combustible gas detectors, although gases that burn are, by definition, flammable. Combustible gas detector measurements are referenced to the specific gas's lower flammable limit (LFL) expressed as a percent by volume in air. In many systems, the purpose of a detector is to alert operators that the concentration is approaching the LFL or some predetermined fraction of the LFL. These are known as %LFL monitors. Some processes may have general combustible gas detectors that report the total concentration in percent by volume or parts per million.

The %LFL detector reports how close the concentration is to a flammable mixture in ambient air. For example, a concentration of 2.5% by volume of methane, which has a 5% LFL in air, will give a 50% LFL indication. Conversely, an ammonia gas detector needs 7.5% by volume concentration in order to have a 50% LFL indication. The closer to 100% of the LFL, the greater the likelihood of an explosion occurring.

C.1.3 Types of Detectors

C.1.3.1 Electrochemical Detectors

Many toxic gases and oxygen can be detected using a cell filled with a chemical that reacts with a specific gas. Signal levels are low but relatively linear and repeatable. Electrochemical detectors, as illustrated in Figure 1, are the most common technology used for toxic gas detections. These cells are also used for oxygen detection. Electrochemical cells are highly sensitive, which is very useful for toxic gases that can have a STEL of 5 ppm. There are drawbacks to their use, however. They typically need some level of humidity in order to function correctly. They wear out over time, and the higher the concentration the sooner they will wear out. They can also be easily “poisoned” by foreign materials such as silicone.

How electrochemical detectors work:

- The cells are made up of a permeable membrane that will allow the gas to enter but keep the chemicals within the cell.
- The cell has two electrodes on either side of it and it is filled with a chemical known as an electrolyte that will react with a specific gas. When exposed to the desired gas chemical, it will produce an electric charge.
- The charges are collected by the electrodes, resulting in an electric current.
- This current is very low but is relatively linear and repeatable.
- The current reading is converted to a ppm indication.

C.1.3.2 Catalytic Bead Sensors

One of the earliest forms of combustible gas sensors is a catalytic bead, illustrated in Figure 2. Catalytic beads will react to almost all combustible gases; therefore, one version of hardware with a minor change to the firmware can be used to measure a variety of combustible gases. Some detectors are actually user-programmable to detect different gases.

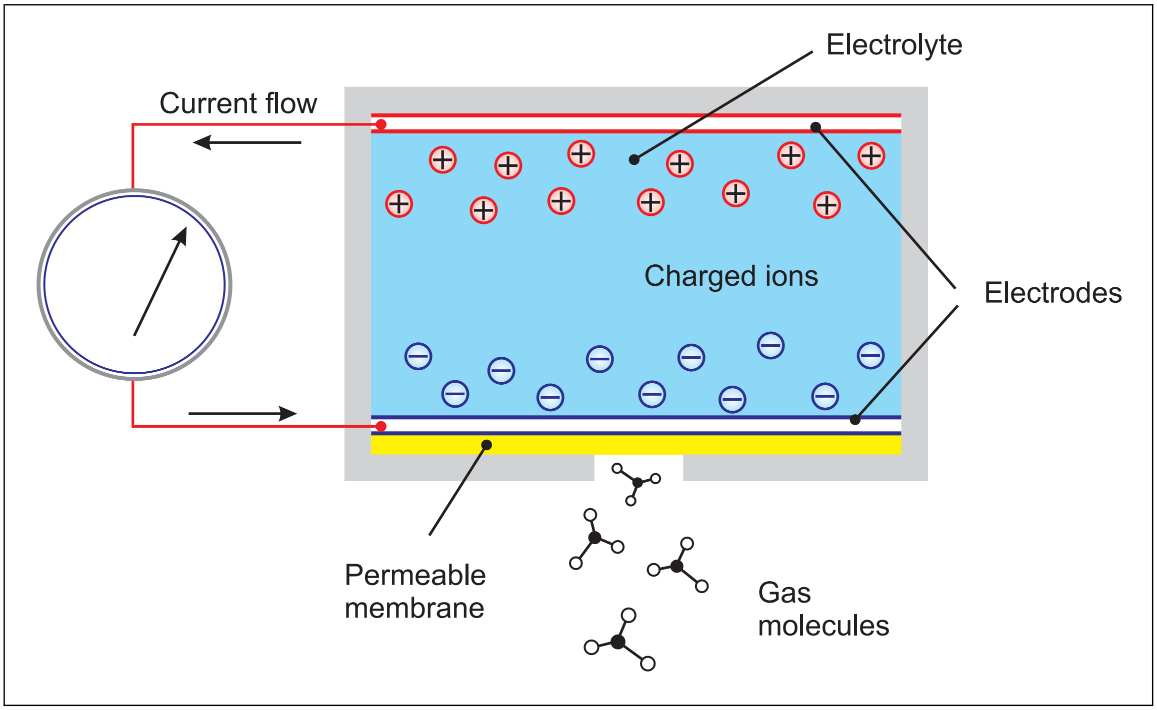

Fig. 1. Electrochemical detector

However, catalytic beads are subject to inhibitors. Inhibitors coat the beads, preventing them from oxidizing the gas. When the beads are exposed to clean air they can burn off these inhibitors and will eventually recover. Catalytic beads are also subject to poisons; based on the time and concentration of the poisons, they can either reduce the response of the signal or even destroy the sensors. One of the worst poisons for catalytic beads is silicon. Silicon gases act quickly in low concentrations, causing the active bead to overheat and damage or even crack.

How catalytic bead sensors work:

- The sensor is made up of the enclosure; a flame arrestor that allows gas to enter the cell but, when ignited, prevents the ignition from propagating to the ambient air; a reference bead; and an active bead.
- The two beads are connected in what is known as a bridge circuit.
- One bead, the reference, is encased in glass.
- The second bead is impregnated with a catalyst that oxidizes the gas. The higher the concentration, the greater the rate of oxidation, the hotter the bead will get.
- The higher temperature causes a change in the resistance of the bead.
- The bridge circuit measures a change in voltage across the bead, which correlates to a gas reading.
- The purpose of the reference bead is to compensate for environmental conditions such as temperature, pressure, and humidity.

C.1.3.3 Infrared Absorption Detectors

A more modern version of a combustible gas detector is infrared absorption or IR sensors, illustrated in Figure 3. This type of sensor only works with hydrocarbon gases. The hydrocarbon bonds within the gas absorb certain wavelengths of IR light. The amount of absorption is directly dependent on two main factors: the gas concentration and the path length of the beam.

The specifics of the absorption are the basis of the technology. The IR sensor works on the same principle as the catalytic sensor.

When choosing an IR sensor there are a number of things to consider:

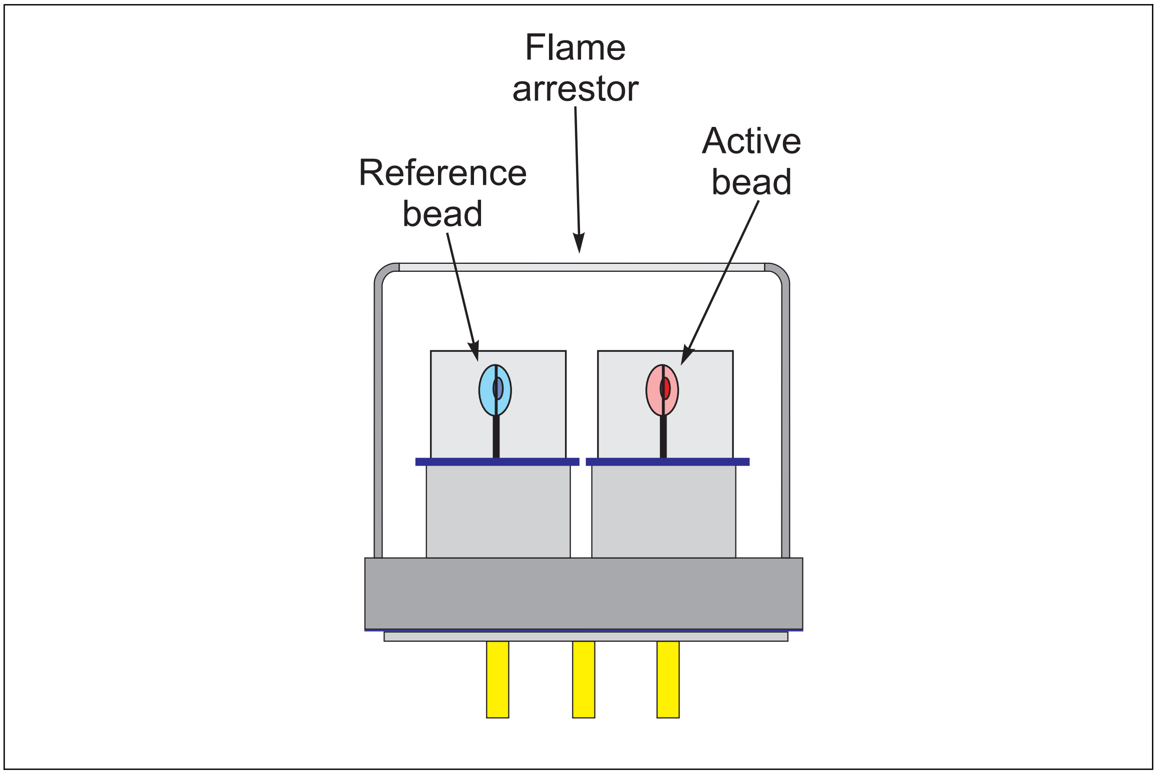

Fig. 2. Catalytic bead sensor

- These sensors respond to many hydrocarbons.
- Because the gases do not come in contact with the actual source of measurement, they are highly resistant to poisoning and etching.
- Unlike catalytic sensors they do not require oxygen to make the measurement reading; therefore, they are not affected by the oxygen concentration.
- They also have a minimal drift, which means the calibration cycle time can be extended far longer than for a catalytic bead detector.

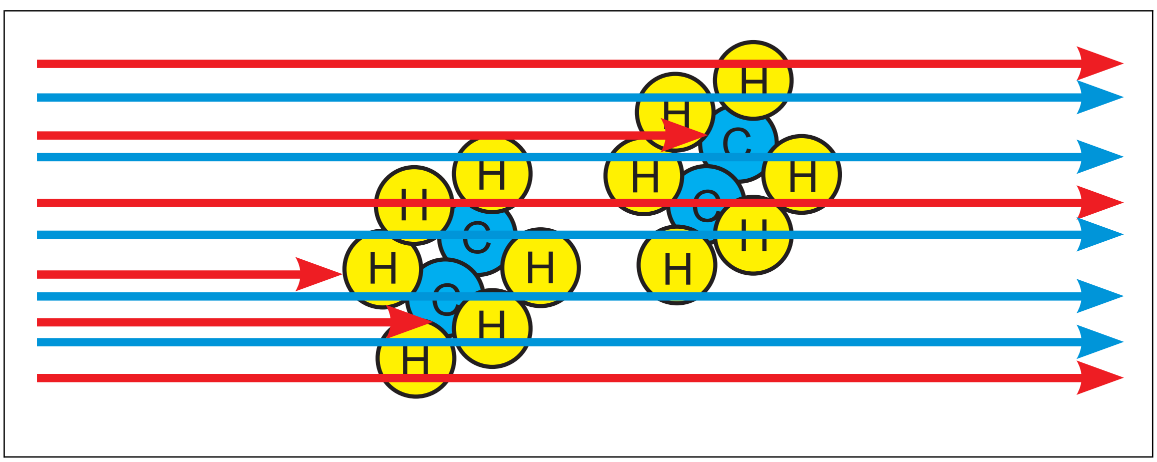

Fig. 3. Infrared absorption detection