Considerations For Effective Gas Detector Siting

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Introduction

Gas detection systems provide warning to plant personnel of a release of a combustible gas so that actions, automatic and/or manual, can be taken to control the release before any significant damage can occur. These actions can include process system shutdowns and suppression or mitigation systems actuation. A well designed gas detection system will increase the level of plant safety.

Deciding the objective of the system at the start of the design and using gas release and dispersion modeling are essential to provide an effective gas detection system. Unless you have an unlimited budget and can locate a sensor at every possible release point, the use of computer models can help you to locate gas sensors in a cost-effective manner. The scope and purpose of the detection system must be defined at the beginning of the design to ensure consistency throughout.

Objective of Gas Detection System

The principal objective for the detection of gas releases should be to reduce the likelihood of fires and/or explosions and prevent excessive property damage, interruption to plant production, injury, and loss of life. An additional consideration is the toxicity hazard (ultimately the life hazard) created by a leak of a gas with both toxic and combustible properties.

The objective of the gas detection system should be clearly defined at the beginning of the project to ensure that the analysis of the hazard, equipment selection and detector placement are consistent with the reason for installing the system. These parameters will vary depending upon the area of the plant involved. The system may be used for alarm only in a liquefied gas storage area because there are a no ignition sources and the area is remote from other processes. In another area, the purpose may be to initiate process shutdowns and actuate water spray systems to dilute a release.

Part of the overall design should include the procedures which address the actions to be taken by plant personnel when the gas detection system alarms. This should include what actions are to happen at the various alarm levels, actions to be taken in specific plant areas, and what effects the plant condition (shutdown, normal, upset) has on these actions.

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Hartford Steam Boiler

Chemical Properties and Process Conditions

After the system objective is determined, gathering of data is next. The materials that you want the detection system to sense must be stated. The release identification will include an assessment of the chemical and physical properties of the materials of concern, and the process conditions present. These properties and conditions are used by the modeling calculations to determine various characteristics of the releases, including material release rate, release plume shape and size.

The range of flammability for the materials is considered. This property provides insight into the likelihood of a release being ignited before it dissipates. The boiling point and latent heat of vaporization for each material is considered for the specified scenarios. These physical properties are useful in assessing the volatility of the materials as used.

Materials that exist under ambient conditions as flammable gases are considered as gases when they are released. Materials that exist under ambient conditions as liquids may be considered as liquids or vapors, depending upon the process conditions.

Process parameters of temperature, pressure, and flow rate, are considered in conjunction with the material properties to evaluate the potential for fire and explosions. An example is a combustible liquid below its flash point may not be a significant problem if released, but if released from part of the process when it is 100 F above its flash point it is a problem. These parameters along with the quantity of materials that could be released are considered to evaluate the size of potential releases. The process parameters are used to assess the nature of the releases anticipated in the specified scenarios.

The following is an example of the criteria for release scenario selection used on a recent project. The sections of the process to be analyzed for gas detection siting were those pieces of equipment where any one of the following conditions were present:

- Liquefied flammable gases are involved
- Flammable/combustible materials are at temperatures above their flash point.
- Flammable/combustible gases are at greater than 500 psig

These criteria listed above are only an example. You must decide the boundaries of what is to be analyzed. Too wide a boundary and the analysis becomes overwhelming. Too narrow a boundary and it is likely that significant release scenarios are not included.

Most, if not all, of the material properties and process conditions are available in the Process Hazard Analysis (PHA). If a PHA has not been done or does not have the required information, the data can be obtained from the P&IDs and process flow diagrams. The process engineer and unit operators are the most knowledgeable people of a particular process and can provide valuable information on the process.

Failure Mode Selection

You must decide the types of possible release points to analyze. Assume that reasonable failures can occur. Analyzing the instantaneous rupture of a large vessel or a double-ended shear of a welded steel pipe for gas detector location is unreasonable. The catastrophic event can occur, but effective detection concentrates on the more likely events. These are the type of events that usually are the smaller releases which can be controlled if detected quickly and appropriate action is taken. Typical failures to considered are: pump/compressor seal failures, flange failures, tubing connection failures, instrument connection failures, hose and flexible connection failures.

Release Locations

The next step is to determine possible release locations. These are locations where the material types, material conditions and typical failure mode conditions coincide. The release locations should be individually analyzed to gather all the required data for the release and dispersion modeling. This will include the opening size, elevation and orientation, and process parameters at the release point.

The release scenarios and their locations should be reviewed and approved by those people directly involved with the unit or plant before commencement of the preliminary modeling effort. The process engineer and the unit operator have the detailed knowledge of the area under consideration. They can help provide information that will increase the validity of the release scenarios chosen. If possible, include the process engineer and unit operator in the project team from the beginning.

Meteorological Considerations

Before dispersion modeling is started, the meteorological conditions at the site should be investigated. Meteorological parameters including prevailing wind speed, direction, atmospheric turbulence, and thermal conditions should be considered. Parameters are selected which present the “worst case” conditions for detector siting criteria. The worst case meteorological conditions for detection may not be the prevailing conditions at a site, but are within the range that may occur there.

Release and Dispersion Modeling

Once all the information has been gathered on the release scenarios, combined with release location specific physical information, modeling of the releases is next. The dispersion model will provide information on the size and concentration of the gas being dispersed at various times throughout the release.

The computer model can determine the release rate of the material, its condition at the release point. The material may be released as a vapor, liquid, or flashing liquid. Expansive cooling may have changed the temperature of the material which may have a significant impact on the dispersion. The model will provide the information necessary to determine the extent of the hazard due to the release.

Similar releases should be grouped to eliminate unnecessary model runs. If there are seven potential releases of the same material that vary in temperature by 20 F, little is gained by running the dispersion model seven times. Sensitivity checking of the dispersion results should be done to determine the effect that varying input parameters, such as weather conditions and release orientation may have on the dispersion results.

Many models are not accurate in estimating the concentrations near the source term, or release point. They can, though, provide data on the extent of the hazard. This can be used to quantify which of the releases present a greater hazard to the plant and/or surrounding community. One release may not show any effects beyond the release point, while another shows a combustible gas cloud that extends to fired heaters located across from the selected release. The second case reveals a higher hazard due to the possibility of a combustible mixture reaching an ignition source, compared to the first release which was confined to the general vicinity of the release. The model can help you determine where gas detection placement should be given a priority.

There are a number of different computer modeling programs available to use for gas dispersion modeling. This paper's purpose is not to review the modeling programs but to suggest how they can be used to assist in locating gas detectors. A few of the programs available are: SuperChems® by A. D. Little and CHARM® by Radian. There are also several public domain programs such as ARCHIE, DEGADIS, CAMEO and SLAB. Each program has its own advantages and disadvantages in terms of ease of use, output options and modeling capabilities. Some models will do release and dispersion modeling in one step. Others require separate models be run and the output from the release model be fed into the dispersion model. You must determine if the model being used is appropriate of the situations being considered in your specific case.

Detector Siting

The detector siting criteria considers detecting a product release before a vapor cloud capable of supporting deflagration can be formed. While 5 metric tons of released material is considered the minimum necessary for deflagration, smaller quantities can also create quite severe flash fires. The release should be detected as early as practical to allow time for personnel to take corrective action before a vapor cloud forms.

Different detection location criteria for different areas of a plant are often developed. As an example, more rapid detection of smaller quantities of gas is needed in the process areas than is needed for storage areas. In a process area, there are numerous ignition sources. Should an accumulation of combustible vapor contact an ignition source having sufficient energy, a flash fire would result. The congestion of process areas has shown in some cases to accelerate a flash fire. Therefore, detecting small quantities more rapidly is appropriate in process areas.

Larger releases can usually be tolerated in storage areas because of features such as the limited ignition sources present, the lack of congestion from equipment and structures, and the larger mass of the equipment and structures in these areas. The larger mass of equipment and structures in these areas provides additional time during a fire incident to absorb the thermal impact of a fire incident. A larger product release could be considered for storage areas.

Example

An example of release scenario identification, gas dispersion modeling, and detector siting criteria used on a recent project is based on detection at a concentration level of 20% of the Lower Explosive Limit (LEL) of a product released from the process through a 1/4-inch orifice within 1 minute or before 1,000 pounds of material is released. This criteria was used to provide time for operating personnel to take corrective action to reduce the quantity of product released. This criteria also provides detector siting that is not so sensitive as to cause “nuisance” alarms.

The detector siting used in this project is not dependent on wind direction. In this case, the prevailing wind direction varies. The detector siting criteria considers placing the detectors within an area defined by the dispersion concentration isopleth width at the release point. The isopleth width at the release point defines a circular area that approximates the distance the release will travel upwind. This results in detector placement with a higher probability of release detection under varying wind directions instead of relying on prevailing wind directions. Murphy’s Law would indicate that if there is going to be a release and the detector location is based on prevailing winds, the wind will be blowing 180 from the direction used.

The use of state of the art data gathering methods, computer modeling, and gas detection equipment is not a substitute for common sense. When the detectors are installed, care must be taken to avoid placing the detector where it is shielded from the source of the release.

Gas Detection System Components and Functions

A combustible gas detection system consists of several components including the sensor, indicating monitors, audible alarms, and visual alarms. The system may also have the capability of interfacing with other plant control and monitoring systems.

Combustible gas detection systems are typically arranged to signal an alarm at two different levels of gas concentration. The system could activate output alarm devices and also signal that a specific level of combustible gas exists. Two common alarm set points are 20% LEL and 40% LEL. At 20% LEL the system activates a warning light at the panel and a local alarm in the area of the sensor causing the alarm. This could allow for evacuation of the area, increase in ventilation rate and/or an immediate check of the area by qualified personnel. At 40% LEL, the system provides another alarm light, expands the audible/visual alarm beyond the local area, automatically shuts down and/or vents process equipment, activates vapor dispersion systems, and pages emergency personnel so that they could take appropriate action.

Regardless of the specific system arrangement, essential components of the system are the ability to distinguish the specific monitor that activated the alarm (therefore its location), the gas it has detected, and the gas concentration. Without this information, effective actions will be limited. There are many ways of organizing this information and recalling it when needed.
Simple labeling may be an answer for small systems. Compiled data sheets may work for another. However, most installations now incorporate programmable logic systems that can be interfaced with the gas detection equipment. In this way, excellent information recall capabilities exist. Therefore, upon detection of a combustible gas by a monitor, all pertinent information related to the incident can be displayed instantaneously on a computer screen.

Types of Gas Detectors

There are two types of gas detectors in use today for combustible gases. These are the single location point type and the beam type. Both types have the own uses and advantages and disadvantages.

The point type uses a catalytic bead as a sensor. The bead is heated so that when a combustible gas is present at the sensor, it will burn, thereby raising the beads temperature. The rise in temperature changes the resistance through the bead. The resistance change is compared against a reference bead in the detector to account for ambient conditions. The system will relate the resistance change to a percentage LEL (Lower Explosive Limit).

Beam type detectors use the fact that hydrocarbons absorb infrared radiation at characteristic wavelengths. The beam type detector projects a detection and reference beam across a space. The beam goes to either a separate receiver or is bounced off a mirror if the device is a combined transmitter/receiver. The beam can be projected up to 100 meters (328 feet).

The typical characteristics of both types of detectors are shown below. These will vary depending upon the specific manufacturer of the detector. Each of these factors should be considered when choosing the most appropriate device.

Point-type Detectors

– Ideal for monitoring at specific locations or equipment components, such as air intakes to control rooms or an isolated piece of equipment.
– Quantifies the gas concentration at a given location.
– Relatively low cost units.
– Sensor replacement is simple.
– Subject to poisoning by certain materials, such as silicon compounds.
– The gas must reach the specific detector (accuracy will be compromised if the detector is placed incorrectly, or too few are used).
– Can give false readings due to interference.
– Frequent maintenance required to check calibration.
– Operating life may be shortened by the presence of persistent background gases.

Beam-type Detectors

- May be more cost effective than point-type detectors, if the potential release locations are in a row, such as a row of pumps along a pipe rack.
- Low maintenance, since equipment is not subject to poisoning.
- Provides gas-release surveillance over a large area.
- Unaffected by high background gas levels.
- Provides average concentration over a short distance (does not give precise concentration at a given location).
- The beam emitter must have line-of-sight with the receiver or reflector (activity in an area may interfere with the beam, leaving an area without detection).
- Service is costly and time consuming, since replacement of failed sensors requires skilled technicians.

The use of point-type gas detectors, as opposed to beam-type gas detectors, may be the most appropriate for areas where the overlapping of the dispersion circles allows a single point detector to sense a release from more than one source. A beam type is more appropriate when there are a series of possible release points in a straight line or if you want to sense a gas release before it crosses a process block boundary. A complete system may mean using both types as appropriate.

Summary

A clear objective for the gas detection system must be set at the beginning of the analysis. What you hope to accomplish must be stated, so a plan can be developed to meet this objective.

The use of release and dispersion models can assist in effective locating of gas detectors by providing information on the size of releases given the failures that are assumed. The model may indicate that the gas releases from some of the failures that could occur in an area, do not release sufficient materials to be of an immediate concern. In this way you can concentrate your efforts on the more serious releases and spend your budget more effectively.

Siting the gas detector in a region coincidental to several dispersion concentration isopleths can reduce the number of detection points needed. A single device will be in a location that allows it to detect a release from several nearby locations. An example would be, a detector located between two adjacent pumps, could detect releases from either pump, depending upon the distance between them.

The use of state of the art data gathering methods, computer modeling, and gas detection equipment is not a substitute for common sense. Modeling is just an approximation of what might happen under a given set of conditions. Be sure to get the input of the people most familiar with the plant, they may have information that renders the results from the most sophisticated model useless, if the wrong assumptions are made.

Beam-type and point-type gas detectors both have appropriate applications, which will vary depending upon the situation. A cost effective solution means looking at all the available detection options. What may work in one area of the plant, may be completely inadequate in another area.