GAS DETECTION

Early gas detection saves lives

Gases and vapours other than air can pose a threat to human life. The exact nature of this threat depends on the gas present, but in general we divide gas hazards into three main categories:

- *Combustible*
- *Toxic*
- *Asphyxiant*

Combustible gases can burn or explode, possibly causing extensive damage to plant and personnel. The words flammable and inflammable are sometimes used in place of combustible. Commonly encountered examples of such gases are ethane, butane and acetylene, although the complete list of combustible gases is extremely large.

Oxygen behaves differently to air, compressed air, and other inert gases. It is very reactive. Pure oxygen, at high pressure, such as from an oxygen cylinder, can react violently with common materials such as oil and grease. Other materials may catch fire spontaneously. Nearly all materials including textiles, rubber and even metals will burn vigorously in oxygen.

Toxic gases have an adverse affect on human health, ranging from symptoms such as mild headache, through various illnesses, to death. The effects are various with the nature of the gas concerned, and are usually also dependent on the concentration, frequency and length of exposure (total dose). Common toxic gases include carbon monoxide and hydrogen sulphide.

Asphyxiant gases prevent the body from getting sufficient oxygen for its needs. Usually this is simply by the heavier than air inert gas pushing out the air in the atmosphere, such as in a confined space. But sometimes by preventing the body using the oxygen, which is present, as, for example, in the case of hydrogen cyanide.

Note that many gases fall into all three hazard categories. For example, carbon monoxide is combustible, toxic and asphyxiate in nature.

First let us look at combustible gas.

For a combustible gas to ignite, three conditions are needed:

- *The presence of combustible gas in sufficient quantities*
- *The presence of air, or oxygen, in sufficient quantities*
- *The presence of a source of ignition with sufficient heat*

These are the three sides of the traditional Fire Triangle.

Note that the gas must be present in a high enough concentration to ignite. The minimum concentration needed is called the Lower Explosive or Flammable Limit - LEL or LFL. As the flammable/explosive gas concentration increases, so the gas starts to displace the oxygen/air, and eventually there is insufficient oxygen for combustion to occur. The gas concentration at this point is called the Upper Explosive Limit/Upper Flammable Limit or UEL/UFL. Some gases, such as ethylene oxide, need no external oxygen to ignite, and so have a UEL of 100%.

Sensing technologies for combustible gases

For detection of combustible gases, the most common choices are catalytic and infrared sensors.

Catalytic sensors detect a wide range of combustible vapours, including hydrocarbon, hydrogen, and acetylene. Catalytic sensors offer good repeatability and accuracy with fast response time and low initial cost. A catalytic sensor's greatest weakness is that at high combustible gas concentrations, there might be insufficient oxygen to catalyse all of the combustible gas, resulting in a decreased signal of gas concentration less than 100% LEL. Catalytic sensing requires routine calibration - typically, every three months or less. Catalytic sensors are susceptible to poisoning from exposure to a substances such as silicones, halogens, tetraethyl lead, acid, pvc vapours, and other corrosive materials. Sensors can fail without annunciation, hence the requirement for routine calibration or bump testing.

Infrared (IR) detectors are immune to poisoning from contaminants and require less maintenance than catalytic. They are unaffected by prolonged exposure to gas, high gas concentrations, and changes in oxygen level. Unlike catalytic sensors, some IR detectors are fail-safe, meaning that the instrument checks itself and reports any internal condition preventing detection capability. IR sensors can detect only hydrocarbon-based gases and vapours. IR sensors do not detect the presence of substances such as hydrogen (H_2), carbon disulfide (CS_2) or acetylene. Apply IR sensors in combustible gas applications where hydrocarbons are present.

Toxic gas

More people die from toxic gas exposure than from explosions caused by the ignition of flammable gas. It should be noted that there is a large group of gases which are both combustible and toxic, so that even detectors of toxic gases sometimes have to carry hazardous area approval. The main reason for treating flammable and toxic gases separately is that the hazards and regulations involved and the types of sensor required are different.

Toxic gases pose a completely different type of hazard from combustible gases. Usually the hazard is present at much lower concentrations than the LEL. Because of this, the concentration is measured in different units. The part per million (ppm) is often used: one ppm is one molecule in a million molecules. An alternative is the milligram per cubic metre (mg/m^3). The relationship between ppm and mg/m^3 is not straightforward - it depends on the molecular weight of the gas, as well as the temperature and pressure.

Different toxic gases will have different effects on the human body - some of these can be fatal. The severity of the effect is usually dependent on both the concentration of the gas present, and the time of exposure. For example, a five minute exposure to 2,500 parts per million of carbon monoxide causes no effect on man (although it will kill a canary), whereas a 160 minute exposure to 500 parts ▶

"PORTABLE DETECTORS CAN BE DROPPED FROM HEIGHTS, SUBMERGED UNDER CONTAMINATED WATER OR COVERED IN DIRT OF VARIOUS SORTS"

per million may kill a man (while leaving the canary quite happy). Therefore, acceptable limits of toxic gases are usually quoted in terms of a Time Weighted Average. That is, an average concentration over a given time. The Long Term Exposure Limit (LTEL) is the acceptable concentration for an eight hour working period, and the Short Term Exposure Limit (STEL) is the acceptable concentration for a short time period - typically somewhere between five and 15 minutes, depending upon the country.

Sensing technologies for toxic gases

Currently, two main fixed detector types are available to detect toxic gases: electrochemical cell and metal oxide semiconductor (MOS) sensors. Electrochemical sensors are generally considered to be the workhorses for toxic gas detection since they are relatively stable, repeatable and consistent. Used to detect a wide range of different toxic gases in a variety of different applications, electrochemical sensors are available in different sizes and packages. Electrochemical gas sensor limitations include restrictions in very hot and very cold environments. Some sensors use an electrolyte that can evaporate in hot, arid conditions. They are generally not failsafe, meaning they must be visually inspected and routinely calibrated to ensure proper operation.

MOS sensor strengths include long life, wide operating temperature range and excellent performance in low humidity environments. Historically, MOS sensor stability was not ideal in regions prone to major changes in ambient relative humidity. However, nanotechnology MOS sensors are now available that significantly improve MOS performance in both arid and humid environments. These new sensors enhance sensor speed of response to dangerous hydrogensulphide gas concentration levels.

Asphyxiate gases

The problem of asphyxia is caused by a lack of oxygen for the body to use. Rather than measuring the concentration of unwanted gas, it is more usual to measure the oxygen level to check that it is between acceptable limits.

Normal air contains around 20.8% of oxygen, by volume. It is generally accepted that no adverse affects are observed down to 19%. At 16% headaches and other symptoms become apparent, and there is a risk of death at around 14%, which increases until at 6% you have little chance of recovery.

Alarm levels are generally set at 19%. This is less than 2% below normal levels, so it is important that sensors are stable in order to avoid false alarms. Another cause of asphyxia is when toxic gases have the effect of preventing the body from using the available oxygen. Carbon monoxide is one gas that has this effect. For these gases, oxygen monitors will, of course, be of little practical effect, and it is important to monitor for the asphyxiate gas itself.

Gas detection systems usually fall into three categories:

Portable detectors: carried by an individual or group of individuals. Often subjected to some of the harshest treatment of any gas detectors - such as being dropped from great heights, submerged under contaminated water and covered in dirt of various sorts. High quality design and construction is essential for equipment subjected to such treatment.

Fixed systems: permanently attached to a given location. Such systems vary widely in their requirements, from simple, single sensor installations on relatively clean locations, to systems of several hundred detectors with complex control requirements.

Addressable systems: the use of data highways for the data acquisition and control functions associated with gas detection and other functions are now very common. Use of experienced engineers minimises the possibility of problems associated with such systems, and their interface with other devices.

Considerations

Does the gas go up or down?

The vapour density of a gas is a measure of how heavy it is relative to air. Gases which are heavier than air, tend to fall towards the ground, whereas those that are lighter than air will tend to rise upwards.

This has obvious implications with regards to the best positioning of a sensor in order to detect any gas leaks. If no other factors apply, then sensors for lighter than air gases should be positioned high, and those for heavier than air, low. However, other factors often do intrude. Standards such as BS 6959 1989 should be referred to for detailed information, but it is normally wise to consider such things as:

- *Wind direction and strength*
- *Ground topology - does the site slope in any particular direction?*
- *Where are the likely sites of any leaks?*
- *Where are the likely sites where gas could accumulate?*
- *Is there any plant or machinery which may be hot enough to cause convection?*
- *Currents?*

In addition, for toxic gases, it is quite common to position sensors in the breathing zone of personnel working in the area, which can often provide more effective protection than relying on vapour density considerations alone.

Flash point and auto ignition temperature

Liquids (and, in fact, solids) will give off vapour. The concentration of vapour given off increases as the temperature goes up. Eventually, if the temperature is high enough, the concentration of vapour will reach the LEL concentration. At this temperature, called the flash point, the vapour can ignite if the other necessary conditions - oxygen, source of ignition - are present.

Some substances, such as methane, have such a low flash point that they are capable of ignition at all normal temperatures. Others, such as diesel or kerosene, have a flash point above normal ambient temperatures. This means that however large the release, the concentration of vapour will never reach explosive levels - unless, of course, there is a source of heat in the area.

The other implication of this is that any sensor will not detect LEL concentrations, however large the spill - this is, of course, because an LEL concentration is not present, again unless the temperature is elevated. This has obvious implications for the setting of alarm threshold values for leak detection. For the detection of high flash point vapours it may be worth ▸

considering a sensor with a lower range than the normal 0 - 100% LEL, and a common range in these cases is 0 - 10% LEL.

The Auto Ignition Temperature of a gas is the temperature at which it will ignite without the need for a flame or spark. An example of this would be ignition on contact with a soldering iron or hotplate. This has implications as to the permitted T rating (see certification) of any certified equipment used with a particular gas. It is essential that the T rating is high enough to prevent the equipment reaching temperatures which may ignite any gas that is present.

General principles (from HSE)

The following aspects should be considered with respect to leak/gas detection:

- *Human behaviour*
- *Objectives of leak/gas detection systems*
- *Types of leak/gas detectors required*
- *Maintenance of leak/gas detectors*
- *Management of leak/gas detector systems*

The following issues may contribute towards a major accident or hazard:

- *Unrecognised high-risk areas, where detectors could be used*
- *No detectors or the wrong types in place in high risk areas*
- *Detectors incorrectly positioned and installed on site*
- *Poor level of maintenance and control of detection systems*
- *Too heavy a reliance on ineffective detectors*

Contributory factors concerning leak/gas detection

- *The appropriateness of the types of detectors being used (UV detectors, IR detectors, smoke detectors, intrinsically safe detectors, heat detectors, specific substance detectors, explosimeters) in terms of the environment in which they are located and to perform the duty expected*
- *The effectiveness of using the detectors in terms of their positioning relative to the possible leak sources, taking account of dispersion and dilution of the released gases/vapours*
- *The effectiveness of the detectors for the types of substances to be detected (flammable substances, acid gases, smoke, explosive substances, toxic substances) at the concentrations required. Detectors may be chosen to react to more than one substance*
- *The types of protective devices linked to the detection systems (alarms, warning lights, reaction quenching systems, isolation systems, fire retardant systems, plant shutdown systems, trip devices, emergency services)*
- *The reliability of each detector (range of detection, response time of detection, level of maintenance, calibration frequency, performance testing frequency, proof testing)*
- *The detectors can be clearly seen, heard and understood, (appropriate warning signs, lighting, noise recognition), on plant, in the control room and off-site (if appropriate)*
- *The procedures to respond to alarms, as a result of a leak/gas being detected (emergency evacuation plans, fire drills, risk assessing existing emergency evacuation plans), to confirm that the release has actually occurred and to record and investigate false alarms and take action to change the system to maintain the confidence of operators*
- *The level of risk associated with each potential leak source (risk assessments, risk-rating systems) and the reduction in that assessed risk value achieved by the use of detectors*
- *The provision and accessibility (to operators or maintenance staff) of a sufficient site plan which maps all potentially hazardous areas (zones 0, 1 and 2, segregation of compatible hazardous substances)*
- *The detectors conform to British Standards such as BASEEFA (British Approved Service of Electrical Equipment in Flammable Atmospheres), if required*

Contributory factors concerning fire detection and control

- *The types of fire detector systems in place (infrared detectors, ultraviolet light detectors, temperature detectors, smoke detectors)*
- *The area covered by the detection system*
- *The reliability of the fire detection systems (fail-to-danger faults, spurious alarms)*
- *The types of fire protection systems in place (fire proofing, water sprays, foam/filming agents, monitor guns, combustible gas monitors, foam on tanks, fire walls/barrier walls, emergency relief venting for buildings, dust explosion control)*

Major hazards

The Safety Report should address the following points:

- *Detector fails to detect in time (e.g. response time of instrument and/or response to high reading/alarm failing to prevent a major accident)*
- *Detector fails in undetected unsafe state (reading zero)*
- *Alarms, warning devices and protective devices fail to operate on demand*
- *A leak occurs which cannot be detected (due to position of sensor or weather conditions)*
- *Maintenance procedures not followed, increasing unavailability of system or rendering system ineffective*

Guidance and codes of practice relating to leak/gas detection

The following publications can be used as guidance material relating to safety issues surrounding the use of gas/leak detectors:

- *HS(G)22 Electrical apparatus for use in potentially explosive atmospheres, HSE, Not in current HSE list. Paragraphs 6 - 18 refer to eight types of protection against ignition in a potentially flammable atmosphere. Paragraph 20 refers to flameproof equipment having to meet BS 5501: Part 5: 1977. Also, all electrical apparatus must be approved by BASEEFA if used in flammable environments. Paragraph 51 refers to maintenance schedules listed in BS 5345. Paragraph 58 refers to the relevant legislation applicable to electrical apparatus in explosive atmospheres*
- *LPGA CoP 1 Bulk LPG storage at fixed installations. Part 1: Design, installation and operation of vessels located above ground, LP Gas Association, 1998. Supersedes HS(G)34 Storage of LPG at fixed installations, HSE, 1987. Part 1, Appendix A.1 recommends the use of suitably calibrated explosimeters to test for leak detection*
- *HS(G)34 Storage of LPG at fixed installations, HSE, 1987. Paragraph 21 refers to containment pits where it recommends that gas detectors be installed in case of leaks*
- *HS(G)176 The storage of flammable liquids in tanks, HSE, 1998. Paragraph 35 refers to electrical apparatus used in explosive atmospheres and refers to BS EN 60079-10.*
- *HS(G)113 Lift trucks in potentially flammable atmospheres, HSE, 1996. Paragraph 43 refers to the use of intrinsically safe gas detection systems which will automatically shut down a truck in the event of a spillage or release of flammable vapour in a zone 2. Paragraph 46 refers to gas detectors being constructed to a zone 1 standard and set to operate at 25% of the lower explosive limit of a gas or vapour*
- *CS1 Industrial use of flammable gas detectors, HSE, Not in current HSE list. This document highlights the accuracy, instrument errors and the safety precautions required for the use of flammable gas detectors* ■

References:

Health and Safety Executive, The Abbeystead explosion: a report of the investigation by the Health and Safety Executive into the explosion on May 23, 1984, at the valve house of the Lune/Wyre Water Transfer Scheme at Abbeystead.

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