The selection and use of flammable gas detectors

INTRODUCTION

1 This guidance has been produced by the Health and Safety Executive. It provides advice and information on the selection, installation, use and maintenance of industrial flammable gas detectors. It is aimed at process engineers and managers and others concerned with the use of flammable gas detectors. It is not intended for specialist instrument engineers or those seeking detailed technical information. It does not apply to the mining and offshore industries.

2 This document does not cover toxic gas detectors or detectors used in the home. It does not cover the use of personal monitoring equipment worn to determine exposure to toxic substances and there is no detailed advice on working in confined spaces.

3 For the purposes of this guidance note, the word 'gas' will be used to cover vapours as well as permanent gases.

4 Many industrial processes produce flammable gases and vapours which can burn when mixed with air, sometimes violently. Typical examples include:

- removal of flammable materials from tanks and pipes in preparation for entry, line breaking, cleaning, or hot work such as welding;
- evaporation of flammable solvents in a drying oven;
- spraying, spreading and coating of articles with paint, adhesives or other substances containing flammable solvents;
- manufacture of flammable gases;
- manufacture and mixing of flammable liquids;
- storage of flammable substances;
- solvent extraction processes;
- combustion of gas or oil;
- combined heat and power plants;
- heat treatment furnaces in which flammable atmospheres are used;
- battery charging.

5 Flammable gas detectors can make a valuable contribution to the safety of these processes. They can be used to trigger alarms if a specified concentration of the gas or vapour is exceeded. This can provide an early warning of a problem and help to ensure people's safety. However, a detector does not prevent leaks occurring or indicate what action should be taken. It is not a substitute for safe working practices and maintenance.

SELECTING A SUITABLE GAS DETECTION SYSTEM

Fixed or portable

6 Detectors can be fixed, portable or transportable. A ‘fixed’ detector is permanently installed in a chosen location to provide continuous monitoring of plant and equipment. It is used to give early warning of leaks from plant containing flammable gases or vapours, or for monitoring concentrations of such gases and vapours within plant. Fixed detectors are particularly useful where there is the possibility of a leak into an enclosed or partially enclosed space where flammable gases could accumulate.

7 A ‘portable’ detector usually refers to a small, handheld device that can be used for testing an atmosphere in a confined space before entry, for tracing leaks or to give an early warning of the presence of flammable gas or vapour when hot work is being carried out in a hazardous area.

8 A ‘transportable’ detector is equipment that is not intended to be hand-carried but can be readily moved from one place to another. One of its main purposes is to monitor an area while a fixed gas detector is undergoing maintenance. In this guidance, the word ‘portable’ will be used to cover both portable and transportable gas detectors.

Point or open-path

9 Point detectors measure the concentration of the gas at the sampling point of the instrument. The unit of measurement can be:

- % volume ratio;
- % lower explosion limit (LEL) for a flammable gas;
- ppm or mg/m^3 for low level concentrations (primarily used for toxic gases).

10 Open-path detectors, also called beam detectors, typically consist of a radiation source and a physically separate, remote detector. The detector measures the average concentration of gas along the path of the beam. The unit of measurement is concentration multiplied by path length, % LEL x m or ppm x m. Systems can be designed with path lengths of 100 m or more. However, it is impossible to distinguish whether a reading is due to a high concentration along a small part of the beam or a lower concentration distributed over a longer length. Also, they are not specific to a particular gas, for example steam or water vapour can produce false readings and alarms.

11 Portable and transportable detectors are always point detectors. Fixed gas detectors can be point detectors or open-path detectors.

Type of sensor

12 There are a number of different types of sensors used for gas detection. The choice of sensor depends on:

- the gas to be detected;
- the expected range of concentration;
- whether the detector is fixed or portable;
- whether the detector is point or open path;
- the presence of other gases that may affect readings or damage the sensor.

13 The main types of sensor are listed in the Appendix. This includes a brief description of the operating principle and some of the advantages and disadvantages of each type. More information on point detectors is available in BS EN 50073.[1] There is no equivalent BSI standard for the use of open path detectors but information can be found in BS EN 50241.[2]

Sampling method

14 In many fixed gas detection systems, the sensor units are designed to use natural diffusion as the sampling method. The sensors are located at or near points where there is the possibility of a gas release.

15 However, natural diffusion as a sampling method can be slow. In many cases a faster response is needed, and the sample is transported to the sensor using a sampling pump. This is called aspirated or extractive sampling.

16 Sampling lines are often used in fixed detector installations to transport the sample to the sensor. A possible disadvantage is that it takes a finite time for the sample to travel the length of the sampling line. This delay could be unacceptable in situations where an explosive atmosphere could develop quickly, such as in a solvent-evaporating oven.

17 In multi-point sampling, there may be a number of sampling lines connected to one sensor. The detector processes the samples from each line in a set sequence. This can introduce further delay in the time taken to detect a leak.

18 The materials used for the sampling line should be selected carefully to prevent dilution or contamination of the sample by leakage, diffusion or sorption of the vapours, corrosion, or the ingress of air. The path and location of the line should be chosen carefully to avoid any mechanical damage.

19 Care should be taken to avoid blockages in the sampling line. These can be caused by particulates, water condensation or liquids with a high boiling point. To minimise this effect, a filter may be needed to remove particulates and a trap to remove entrained liquid. It may also be necessary to heat the sampling line.

20 Portable detectors can be used in diffusion or aspirated mode. They can be fitted with probes for leak seeking or testing inside confined spaces beyond the normal reach of the user. Probes are normally rigid and about 1 m in length, although they may be telescopic and may be connected to the apparatus by a flexible tube.

Alarm

21 If a specified gas concentration or set point is exceeded, the detector system should trigger an alarm. The alarm should not stop or reset unless deliberate action is taken. The alarm should be audible or visible or preferably both. The requirements for alarms are specified in performance standards such as BS EN 61779.[3]

22 For a portable gas detector, the alarm is part of the instrument itself. If the instrument is put down for some reason, for example to carry out a task, then it is important that the operator should be able to see or hear the alarm from the work position.

23 An alarm to warn of a fault condition is vitally important because, if a detector fails, it could falsely indicate a safe condition such as showing a zero reading. There should be no non-detectable fault conditions in the detector, where practicable.

24 A low-battery alarm is normally present on portable instruments. The manufacturer's instructions should give details of the expected battery lifetime after charging and the operating time left after the low-battery alarm has activated. If the low-battery indicator does activate, the instrument should be recharged in a safe area, away from the area being monitored, as soon as is reasonable and before the detector shuts down. Depending on the type of sensor, some detectors will also have a low-fuel (hydrogen) alarm.

At what gas concentration should the detector alarm?

25 The gas detector should be set to alarm at a level low enough to ensure the health and safety of people but high enough to prevent false alarms. False alarms are most likely to be caused by fluctuations in sensor output due to environmental changes (eg ambient temperature, pressure or humidity), sensitivity to other gases or vapours, or sensor drift. If false alarms are a problem then one option is to use two detectors - the alarm level must be registered by both detectors before the alarm activates.

26 In determining the required alarm levels for fixed gas detection systems, the following should be taken into account:

- any industry standards and recommendations;
- the lower explosion limit of the gas or vapour;
- the size of the potential leak and the time to reach a hazardous situation;
- whether the area is occupied;
- the time required to respond to the alarm;
- the actions to be taken following the alarm;
- the toxicity of the gas or vapour.

27 A suitable safety margin should also be incorporated to account for ventilation dead spots, where vapours could accumulate, and the variability of natural ventilation. One option is to set two alarm levels. The lower alarm could act as a warning of a potential problem requiring investigation. The higher alarm could trigger an emergency response such as evacuation or shutdown or both. For leak detection purposes (ie not process monitoring), the first alarm level should be set as low as practicable, preferably no higher than 10% of the lower explosion limit (LEL). The second alarm level should be no more than 25% LEL.

28 If gas detectors are installed as part of the process where a flammable atmosphere is expected (eg a solvent-evaporating oven[4]) the alarm levels should take into account normal operating conditions and the maximum safe operating concentration of the equipment. The manufacturer should specify the alarm levels, which could be up to 50% LEL depending on the design of the equipment. If the solvent is changed, checks should be made to ensure that the sampling system, detectors and the alarm levels are suitable for the new solvent.

29 An alarm level can be set on most modern portable gas detectors. Often the level is set at 10% LEL but the above factors and the manufacturer's recommendations should be taken into account.

What actions should be taken on the gas detector alarming?

30 The purpose of a gas detector is to give a warning of a potential problem. The actions to be taken if the alarm sounds should be considered before the detector system is put into use. They should be documented in written procedures. These procedures may be operating procedures or emergency procedures and should be backed up by training and refresher courses.

31 As discussed above, setting two alarm levels may be an advantage in some cases. The procedure at the lower-level alarm could be for personnel to stop their work, put on respiratory protective equipment (RPE), and investigate the problem to determine if it can be easily rectified. The procedure at the higher-level alarm could be to initiate emergency procedures such as shutting the plant down and/or evacuating the building or site.

32 Fixed detector systems can be designed to trigger automatic shutdown of plant and equipment or to increase mechanical ventilation rates. However, such systems are not considered to be sufficiently reliable for the purpose so back-up measures may be needed.

Response time

33 In gas detector specifications the response time is usually defined as the time it takes the output of the sensor to reach 90% of its final value when subject to a step change in gas concentration at its sample point; it is written as T_{90}. The overall response time of a gas sensing system is governed by three factors:

- the intrinsic time it takes for the gas-sensing mechanism to respond (this is dependent on the type of sensor, eg it is determined by diffusion rates for catalytic sensors and spectroscopic transitions for infrared sensors);
- the response time of the signal processing electronics;
- the time taken to transport the sample to the sensor. For pumped (aspirated) systems the transport time is determined by the sample tube length, tube diameter, aspiration rate and diffusion rate from the flow system to the sensor.

34 The required response time will depend on the location, purpose of the system and speed of development of the expected problem. Protection of people from large leaks requires a fast response time but where the gas concentration is expected to build up slowly a slower response time may be acceptable.

35 The response time should also be considered in conjunction with the alarm level (see paragraph 25). For example, a longer response time may be acceptable, if the system alarms to evacuate at 10% LEL rather than 25% LEL, for the same gas leakage rate and detector position.

Avoiding ignition risks from gas detection systems

36 The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002[5] place restrictions on the type of equipment (including gas detection systems) that can be used in areas where explosive atmospheres may occur. Workplaces where explosive atmospheres may occur should be:

- classified into hazardous zones;
- protected from sources of ignition by selecting equipment certified as being suitable for use in hazardous areas. It should have the 'CE' and 'Ex' markings to show conformity with the EPS Regulations (Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996).[6]

INSPECTION, MAINTENANCE AND CALIBRATION

37 Fixed gas detectors should be included in the plant maintenance schedule. The performance of most detectors deteriorates with time, the rate depending on the type of sensor and the operating conditions, for example a dusty, corrosive or damp environment. These factors will affect the frequency of inspection, maintenance and calibration. Ask the supplier for advice - more detailed information is available in BS EN 50073[1] and the COGDEM gas detection and calibration guide.[7]

38 Similarly, for portable gas detectors the user should consider the sensor type, operating conditions, required use and accuracy of the detector and the manufacturer's guidance to assess the frequency of inspection and calibration.

39 Portable detectors should only be used if they are in good condition and are functioning correctly. Every time you use them, inspect them for any damage beforehand.

40 Dents, kinks, bends, blockages and holes in the sample probe may affect the sample and give a false reading. A damaged battery, damaged fuel reservoir or cracks in the casing could make the instrument unsafe or unreliable or both. Contamination, eg water or dust, could give false readings and may damage the instrument.

41 A damaged display would make the instrument difficult or impossible to read and a broken alarm may not register a hazardous situation. Any air inlet filters should be clean in order to allow an unrestricted air-flow into the instrument. It is also important to check the integrity of other parts such as the carrying handle or case and shoulder strap.

42 The frequency of the function checks will depend on the manufacturer's recommendations. For portable gas detectors, these should include checking:

- that a zero reading is obtained in a clean atmosphere away from known sources of detectable gas or vapour;
- for a response to a known flammable vapour;
- the battery charge level is adequate for the job;
- the level of any other reservoirs (eg hydrogen in a flame ionisation detector) is adequate;
- the logging period (if datalogging is required) to ensure all datapoints over the required duration of measurement can be stored in memory.

43 For repair or maintenance, the gas detector should be removed to a safe place outside the area being protected, such as a workshop. A replacement detector will be needed to monitor the area unless the hazard has been removed, for example by shutting down the process or plant.

44 Suitably qualified and trained personnel should carry out the maintenance activities, in accordance with the manufacturer's procedures. If qualified personnel or suitable facilities are not available then the detector may need to be sent to the manufacturer or a qualified repair company.

Calibration gases

45 Ideally, the gas to be measured should be used to calibrate the gas detector. Calibration of fixed and portable gas detectors is normally done using a calibrated gas mixture from a cylinder, supplied by a gas company. The supplied gas mixture should contain the same gases in similar concentrations to those being monitored.

46 When it is not possible to obtain calibration mixtures containing the required gases, another gas mixture should be used which gives a similar detector response to the target gas(es). The detector output is corrected by use of a response, calibration or correction factor. Most detector manufacturers have tables (often programmable in the instrument) that show the calibration gas mixture and correction factor for every target gas or vapour that the sensor will respond to. It must be noted that these tables are model-specific. Different types of sensor (for example infrared or catalytic) will have different correction factors.

47 In some cases it is not possible to calibrate for the exact gas or vapour because it contains many different chemical compounds; petrol vapour is an example. When petrol vapour is being measured the detector can be calibrated using a higher alkane such as heptane or octane, which gives a good approximation. The supplier should provide information on the recommended calibration gas for petrol.

48 If more than one gas may be present and there is no obvious calibration mixture, then it is advisable to calibrate for the least sensitive gas. This approach will lead to artificially high readings of the other gases but will ensure that a flammable concentration is not reached before the detector measures it. Specialist knowledge will be required to determine which gas should be used to calibrate the detector as sensitivity may vary depending on the sensor.

49 Many gas sensors are sensitive to pressure and care must be taken when calibrating instruments that readings are not affected by pressure variations. For example, when using a gas cylinder to calibrate a diffusion instrument the gas should be passed through a calibration mask and out to atmosphere. Excessive flow through the mask will lead to overpressuring the sensor, which will produce false high readings. On the other hand, too little flow will lead to air ingress and a false low reading.

50 For pumped (aspirated) systems it is normal to flow the gas to waste and allow the instrument to draw the mixture from a tee-piece or reservoir in the line. Again, care must be taken not to set the flow too high or low as similar problems will occur as for diffusion instruments. On aspirated systems you should ensure that all joints in the sampling system are secure as leakage into the system will result in lower readings.

51 In all cases, you should be careful about disposal of the waste calibration mixture. It is unlikely that the release of a calibration mixture would build up to flammable concentrations, even in a confined space. But with some calibration mixtures the occupational exposure levels[8,9] could be quickly exceeded.

FIXED DETECTORS

Positioning fixed detectors

52 The components of a gas detection system (sensor, control unit and alarm) can be supplied separately or combined into a single unit. The position of the individual components should be considered carefully.

Sensors

53 Sensors should be positioned to detect any gas accumulation before it creates a serious hazard. Factors to consider are:

- the process plant and equipment;
- the type of sensor (see Appendix);
- the properties and dispersion characteristics of the gas;
- the ventilation patterns;
- other safety issues, eg location of personnel or equipment protection.

54 The number of sensors should also be considered. Failure, or removal for maintenance, of an individual sensor should not compromise the safety of the area being monitored. Duplication (or triplication) of sensors and control apparatus may be required for continuous monitoring and to prevent false alarms (see paragraph 25).

55 The process plant and equipment should be assessed to identify the most likely sources of flammable gas. Examples are:

- leaks from pipework flanges, valves, damaged pipework, hoses;
- flammable vapour produced as part of processes such as drying coated products in a solvent evaporating oven. Positioning of sensors should take into account the likely concentration gradients throughout the equipment.

56 Where there is the possibility of gas entering a confined space, the sensors should be positioned close to ingress points. An example is landfill gas entering a building - the sensors should be located close to drains or underground cable conduits.

57 The path of the gas or its dispersion characteristics will depend on the density of the gas and the ventilation patterns. The density can be used to determine at what height sensors should be positioned relative to the potential source. For example:

- methane (natural gas) is less dense than air so it will rise;
- vaporised liquefied petroleum gas (LPG) is heavier than air so it will fall or remain at low level;
- landfill gas (a mixture of methane, carbon dioxide, hydrogen and trace gases) will have a density depending on its composition. For example, mature landfill sites generate gas with a density slightly less than air.

58 The ventilation patterns for indoor locations will depend on the position and size of louvers, doors and other openings and on the operation of ventilation fans. The ventilation patterns for outdoor locations will depend on wind speed and direction, plant layout and topography. If necessary, smoke tests or computer models can be used to predict how a gas leak will behave and to determine the best place for sensors.

59 The sensors or sample points should not be positioned where they may be susceptible to excess vibration or heat, contamination, mechanical damage, or water damage. This will reduce the operational life of the sensor. If there are no alternative locations some suitable protection should be provided, such as vibration isolation mountings. Ensure that the sensors are accessible for maintenance purposes.

60 General guidance on positioning sensors is currently available in BS EN 50073[1] and HSE Guidance Note *Control of safety risks at gas turbines used for power generation*.[10]

Control panels and instrument readouts

61 It should not be necessary to enter a hazardous area in order to obtain a reading of the gas concentration. The control panel should be sited so that readings can be taken in safety. There should also be access for calibration and maintenance. For example, if a building is being monitored then a suitable position could be on the outside wall of the building (possibly near an exit). This would allow the gas concentration to be checked before entry into the building.

62 It may be necessary to have read-outs at more than one location. For example, one read-out panel could be located in a control room but a second read-out may be needed closer to the plant or equipment to inform personnel working locally.

Alarms

63 For fixed detectors, it may be necessary to have alarms at more than one location - to warn people working locally and to alert the control room. Where gas could accumulate in a confined space, such as a room or a building, then it should be possible to hear or see the alarm (indicating a hazardous situation) before entering the space. The audible alarm should be distinguishable from the fire alarm because different emergency actions are likely to be required. All personnel should be trained in what to do if the gas detector alarms.

PORTABLE GAS DETECTORS

64 Portable gas detectors should only be used by people who have been trained in the technique and in the interpretation of results. Training is usually provided by the gas detector supplier. A typical training schedule could include:

- ensuring that the detector is suitable for the purpose and that it is set correctly;
- checking the instrument is functioning and is reading correctly;
- using the instrument properly to obtain true readings;
- interpreting the results.

65 Personnel should also be trained in:

- the hazards and properties of dangerous substances on site;
- the need for personal protective equipment (selection, correct fitting and use of respiratory protective equipment require specialist expertise and training[11]);
- the action to take if the portable gas detector alarms;
- emergency procedures.

66 Portable gas detectors should only be used after a risk assessment has been carried out to determine whether gas monitoring is appropriate and whether any additional safety precautions should be taken.

67 Portable gas detectors can be used actively or passively. Active monitoring is normally carried out using portable, handheld detectors. The operator carries the instrument around while monitoring. This may be to:

- monitor the general area;
- monitor the atmosphere within a confined space;
- check for leaks from likely sources, eg drains or flange.

68 Passive use of a detector is where the instrument is positioned temporarily in one place to monitor the atmosphere. This temporary installation may be for a period of hours or days. The factors for determining the position of a portable/transportable detector for passive monitoring are the same as for fixed detectors (see paragraphs 52 to 60).

69 In all cases, the operator should switch on the gas detector and note the readings in a gas-free area, before entering a hazardous area. If actively testing an area by walking through it, the operator should hold the sample probe in front to determine if it is safe to continue in that direction. It may also be advisable to sample at high and low levels, depending on the gas properties and the location of the release. When reading the monitor, make sure you avoid trips and falls, for example stand still while checking the instrument reading. This will also give a more accurate reading for that location as it will take into account the finite response time of the equipment.

70 For leak seeking or monitoring known leaks or ingress points the probe should be placed as close to the source as possible with the operator upwind of the source and as far away as the probe will allow while still being able to monitor the readout.

71 For testing atmospheres of confined spaces the sample probe should be positioned inside the space with the operator remaining outside, where practicable. The operator should monitor a number of points inside the space, using extended probes where necessary, to take into account vapour pockets and stratification.

Further details can be found in the Approved Code of Practice on the Confined Spaces Regulations 1997.[12]

72 Many portable gas detectors are multigas detectors. They can detect a range of gases - flammable, oxygen and toxic (mainly carbon monoxide). They are often used as personal monitors to alarm if toxic gas is present or if the oxygen concentration is too low. It is always advisable to check the oxygen concentration first because, as noted in the Appendix, a reduced oxygen concentration may affect the sensor reading.

Instrument readouts and controls

73 The portable instrument readout should be easy to read and the controls easy to operate while the instrument is being carried and used. For newer instruments the readout tends to be a digital display on the instrument body itself. For some older instruments the readout may be a dial on the probe.

APPENDIX: MAIN TYPES OF SENSOR

Flammable gas detectors

Catalytic (Pellistor)
The operating principle of this point detector is that heat is generated during the catalysed reaction between the gas and oxygen in air. The resulting rise in temperature of the catalyst bead (also known as a 'pellistor') causes a change in electrical resistance of a platinum wire embedded in the bead, also acting as the heater, which is a measure of gas concentration. The heated wire is contained within an Ex-certified enclosure with a porous sintered metal insert that allows the gas to enter.

This detector is small and is used for detecting flammable gases from 0-100% LEL. It needs a level of more than 10% oxygen to work correctly. It can give false readings in gas rich atmospheres, ie above the upper explosion limit (UEL). The catalyst can be poisoned by trace gases such as silicones and hydrogen sulphide and the metal screen can be blocked. This can result in drift of the zero point, and loss of sensitivity, so it needs regular calibration and replacement.

Used in portable and fixed instruments.

Infrared
The operating principle is based on the absorption of infrared light by certain molecules which are detected by a decrease in transmitted radiation over a beam path. For point detectors the beam length is short (centimetres). For open-path sensors the source of infrared light is a powerful narrow beam that illuminates the space between source and detector. Alternatively, a mirror is positioned at the end of the path which reflects the beam back to the detector. Gas can be detected anywhere in the beam.

Infrared detectors can be either point or open-path and are used mainly for hydrocarbon vapours from 0-100% v/v. The detectors do not require oxygen, cannot be poisoned and are not ambiguous above the LEL. But they cannot detect hydrogen and are inherently pressure-sensitive. For open-path detectors large spaces can easily be monitored but the alignment of source and detector requires great care and objects in the beam can give false readings. If the sun is low in the sky, stray radiation can enter the detector which may cause interference with the beam. If the beam is uncompensated this can give high readings.

Used in portable and fixed instruments.

Thermal conductivity
The operating principle of this point detector is that gases conduct heat at different rates. If a gas is in a mixture with a reference gas then the concentration can be determined by comparing the thermal conductivity of the mixture and the reference gas. This is typically done by measuring the heat dissipated by heated elements. The out-of-balance voltage from a resistance bridge is a measure of the gas concentration. The bridge compensates for ambient temperature changes.

This detector is used in the range 0.1-100% v/v. It can be used to complement catalytic detectors when they are used above the LEL. It only works well when differences in thermal conductivity between the target gas and reference gas (air) are large, eg hydrogen or methane.

Used in portable and fixed instruments.

Flame ionisation
This point detector operates on the principle that an ionised gas will conduct an electrical current in proportion to the number of ions present. Hydrocarbon gases and vapours are easily ionised and the current flow produced is easily measured. The source of ionisation is a hydrogen flame.

This detector can be used for most hydrocarbon gases and vapours from ppm to % v/v levels. It needs hydrogen to generate the flame and a clean air supply. It is fast and sensitive.

Used in portable and fixed instruments but mainly fixed.

Flame temperature
This point detector operates by monitoring the temperature of a controlled hydrogen flame using a pyrometer. Flammable gas in the air supply to the flame causes the temperature of the flame to change. This change is a measure of gas concentration.

This detector is large and is used for flammable gases from 0-100% LEL. It has a fast response but needs hydrogen to generate the flame and a clean air supply. Halons may cause false readings.

Used in fixed instruments.

Semiconductor
The operating principle of this point detector is that a surface interaction between a gas and a gas-sensitive semiconductor alters the conductivity of the semiconductor. Generally, reducing gases (eg hydrocarbons) drive the conductivity in one direction and oxidising gases (eg oxygen) drive it in the opposite direction. The change in electrical conductivity of the semiconductor is a measure of the concentration of hydrocarbons in air.

This detector can be used for most hydrocarbon gases and vapours from ppm to % v/v levels. It has a non-linear response and needs oxygen. It is sensitive to water vapour and many other gases that may produce a false reading.

Used in portable instruments.

Ultrasonic
The operating principle is that the escape of gas from a high-pressure pipeline or other pressurised systems generates ultrasound, which when detected by an acoustic sensor, can provide a measure of the leak rate.

This is a non-concentration based detector used to detect leaks from high-pressure systems. Theoretically, it provides 360º coverage and does not require transport of the gas to the sensor. Care is needed in placement and false alarms may occur due to other ultrasonic emissions.

Used in fixed instruments.

Photo ionisation

The operating principle of this point detector is the same as for the flame ionisation detector, but the source of ionisation is an ultraviolet lamp.

The usage and range of this detector are dependent on the energy of the UV lamp. Its range is from ppm to % v/v levels. The detector is fast and sensitive but humidity may affect the readings. These detectors are small and can be handheld. They are used for leak detection at very low levels.

Oxygen detectors

Electrochemical

The operating principle is that the gas diffuses through a permeable electrode to its interface with the cell's electrolyte. Here electrochemical reactions take place which alter the electrical characteristics of this electrode. Measurement of these electrical parameters with respect to other electrodes within the cell give a signal proportional to the gas concentration. This sensor measures oxygen from 0-100% (and toxic gases from 0-1000 ppm).

Used in portable and fixed instruments.

Paramagnetic

The operating principle of this detector is based on the fact that oxygen atoms are strongly attracted to a magnetic field, ie they are paramagnetic. Measuring the differential interaction between the magnetic field and the target gas and a reference gas generates a response proportional to the oxygen concentration.

This sensor measures oxygen in the range 0-100%. It has a fast response. If the instrument is calibrated in one direction (eg north-south) and is used in another direction (eg south-north or east-west) there will be some offset. Paramagnetic sensors are not often used in portable instruments because of this orientation dependency and tend to be less rugged than electrochemical sensors.

Zirconia-type

The operating principle is based on zirconium oxide (zirconia) or similar ceramics which conduct electricity by the movement of oxygen ions when heated above 300^{o}C. If the oxygen concentration on each side of a thin plate of zirconia is different, a flow will occur and a voltage will be generated between the two surfaces. Electrodes on the two surfaces will detect the voltage; this is a measure of the difference in oxygen concentration.

This sensor measures oxygen concentration in the range ppb - % (by volume). They are suitable for high-temperature environments and are very sensitive. The sensor produces a non-linear response that is also temperature-dependent.

Used in fixed instruments.

GLOSSARY

Flammable: Capable of burning with a flame.

Flammable range: The concentration of flammable vapour in air falling between the upper and lower explosion limits.

Hazardous area: An area where flammable or explosive gas (or vapour-air mixtures) are, or may be expected to be, present in quantities that require special precautions to be taken against the risk of ignition.

Lower explosion limit (LEL): The minimum concentration of vapour in air below which the propagation of flame will not occur in the presence of an ignition source. Also referred to as the lower flammable limit or the lower explosive limit.

Upper explosion limit (UEL): The maximum concentration of vapour in air above which the propagation of flame will not occur in the presence of an ignition source. Also referred to as the upper flammable limit or the upper explosive limit.

Vapour: The gaseous phase released by evaporation from a substance that is a liquid at normal temperatures and pressures.

Zone: The classified part of a hazardous area, representing the probability of a flammable vapour (or gas) and air mixtures being present.

REFERENCES

1 BS EN 50073: 1999 *Guide for the selection, installation, use and maintenance of apparatus for the detection and measurement of combustible gases or oxygen* British Standards Institution

2 BS EN 50241: 1999 *Specification for open path apparatus for the detection of combustible or toxic gases and vapours. Part 1 General requirements and test methods. Part 2 Performance requirements for apparatus for the detection of combustible gases* British Standards Institution

3 BS EN 61779: 2000 *Electrical apparatus for the detection and measurement of flammable gases* (Parts 1-5) British Standards Institution

4 BS EN 1539: 2000 *Dryers and ovens in which flammable substances are released - Safety requirements* British Standards Institution

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10 *Control of safety risks at gas turbines used for power generation* Plant and Machinery Guidance Note PM84 (Second edition) HSE Books 2003 ISBN 0 7176 2193 6

11 *Personal protective equipment at work. Personal Protective Equipment at Work Regulations 1992. Guidance on Regulations* L25 HSE Books 1992 ISBN 0 7176 0415 2

12 *Safe work in confined spaces. Confined Spaces Regulations 1997. Approved Code of Practice, Regulations and guidance* L101 HSE Books 1997 ISBN 0 7176 1405 0

FURTHER READING

Direct reading devices for airborne chemical contaminants
British Occupational Hygiene Society (BOHS) Technical Guide Series No 15
http://www.bohs.org/mod/fileman/files/tg15.pdf.

FURTHER INFORMATION

British Standards are available from BSI Customer Services, 389 Chiswick High Road, London W4 4AL Tel: 020 8996 9001 Fax: 020 8996 7001 Website: www.bsi-global.com

The Stationery Office (formerly HMSO) publications are available from The Publications Centre, PO Box 276, London SW8 5DT Tel: 0870 600 5522 Fax: 0870 600 5533 Website: www.tso.co.uk (They are also available from bookshops.)

HSE priced and free publications are available by mail order from HSE Books, PO Box 1999, Sudbury, Suffolk CO10 2WA Tel: 01787 881165 Fax: 01787 313995 Website: www.hsebooks.co.uk (HSE priced publications are also available from bookshops and free leaflets can be downloaded from HSE's website: www.hse.gov.uk.)

For information about health and safety ring HSE's Infoline Tel: 08701 545500 Fax: 02920 859260 e-mail: hseinformationservices@natbrit.com or write to HSE Information Services, Caerphilly Business Park, Caerphilly CF83 3GG.

This guidance is issued by the Health and Safety Executive. Following the guidance is not compulsory and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice..

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