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Framework for HSE Guidance on Gas Detectors (On-line Checking of Flammability Monitoring Equipment – Final Report)

HSL/2001/06

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Summary

Objectives

1. To review gas detection equipment in safety critical applications and provide a report on the findings (Phase 1).

2. To develop guidance on the selection, installation, use and maintenance of gas detection equipment in safety critical applications (Phase 2).

Main Findings

1. The principal issues involved in developing HSE guidance for inspectors and users of gas detection equipment in process control and safety, fixed area monitoring and portable monitoring for personal protection have been summarised.

2. There is no BSI standard guide for the selection, installation, use and maintenance of open-path detectors (the equivalent of BS EN 50073:1999 for point gas detectors).

Main Recommendations

1. The information summarised in this report should be used as the basis of HSE guidance on gas detectors for internal use (for inspectors) and as a published HSE guidance document.

2. The development of guidance for specific applications by trade associations, user groups or individual companies should be encouraged.

3. The relationships between gas detector location, alarm level and response time should be explored through a combination of modelling and practical tests for common or critical applications of fixed gas detectors. This would generate more specific guidance on gas detector location which is currently lacking.

Contents

1. INTRODUCTION

The use of flammable solvents is an essential part of manufacturing in a range of industries, e.g. printing, paints and resins, aerosol manufacture and chemical processing. Fires and explosions continue to occur due to the failure of the manufacturers to control the flammable atmospheres associated with the solvents. The key to controlling the problem lies in the ability to monitor the critical parameter, namely the flammable vapour concentration.

Control can be achieved by the use of gas detectors. In recent incidents these have failed to ensure safety due to incorrect installation and/or inadequate maintenance. It is a particular problem in small companies which often do not have the knowledge and expertise to ensure reliable operation of the sensors being used in the gas detectors. Reliability of these systems is likely to become of even more importance with the increasing use of gas detectors as the safety critical component of explosion prevention systems. In these systems there is total reliance on the response of the gas detector to initiate some action to prevent a flammable atmosphere being formed, with no additional safety measures such as explosion relief.

Providing additional guidance on the selection, installation, use and maintenance of gas detection systems was seen as one way of improving their reliability. Previous HSE guidance on flammable gas detectors (HSE, 1987) was withdrawn several years ago. This project was conceived with the aim of developing guidance on the use of gas detectors for safety critical applications in the various types of industrial processes. This guidance should be suitable for use by both large and small companies without the need for sophisticated technical support.

The first phase of the project was a review to establish if such guidance would fulfil a real practical need in the industries employing gas detector systems, and if so the scope and type of guidance that would best meet the need. The result was a definite yes for the guidance, which allowed the project to proceed to the second phase. A summary of the findings of the first phase can be found in section 2 below and full details in the Phase 1 report (Walsh et al, 1999).

The objective of Phase 2 was to gather together the necessary information for HSE's Technology Division to be able to write the required guidance note. This report presents the information collected during this phase of the project and will provide the background and rational for the HSE Guidance Note on flammable gas detectors.

2. SUMMARY OF PHASE 1 WORK AND OUTCOME OF FURTHER VISITS

A two pronged approach was adopted to establish the need for the guidance and its scope. Questionnaires were sent out via CoGDEM (Council of Gas Detection & Environmental Monitoring, the trade association for gas detection equipment manufacturers and suppliers) to manufacturers and suppliers of gas detection equipment. One of the authors (PTW) also attended CoGDEM meetings, including their Industrial Gases Subgroup, which provided additional feedback from manufacturers and suppliers. The second approach was via a series of visits to users of gas detection equipment. Resources and time permitted only a limited number of visits, but these were chosen to try and visit as representative a sample of users as possible. Nevertheless, some common themes emerged from the small sample.

There was a general feeling amongst both users and gas detector manufacturers that HSE guidance would serve a useful role for users of equipment requiring flammable gas detectors. This, however, could only be general advice on their use.

Although the principal aim of this study was to investigate fixed flammable gas detectors used in 'safety critical' applications or required to perform an executive action (process safety), it was apparent that there was a lack of guidance on fixed installations used for general area monitoring (leak detection) and for portable equipment (leak detection).

While HSE guidance would serve a useful purpose, more specific guidance could be produced by the trade associations or equivalent groups of users, where there is some specific knowledge of particular industrial processes. Ideally this industry guidance would be written in consultation with HSE. Some small companies may not, however, have the networks and expertise of a trade association and therefore would not be able to produce or access such guidance even if they wanted to. In this case, advice from instrument suppliers and consultants are all that is readily available. The suggested HSE guidance would be a particularly important starting point to assist in discussions between users and gas detection equipment suppliers.

None of the safety systems investigated in the survey relied on gas detectors alone, i.e. the detectors were not the front line protection system. Other protection systems were used, e.g. intrinsic safety of equipment in the hazardous area. Explosion venting was also used to mitigate the effects if there was failure of the detection system.

Gas detector outputs may be interfaced to central control panels with those from other forms of safety protection, e.g. fire detectors. Actions may be different depending on the hazard, i.e. whether due to a gas leak or actual fire. The action to be taken on a detector alarm can thus be just as important for minimising the risk as the selection, installation and maintenance of the detector. Decisions on the actions to be taken at the different alarm points are thus key to achieving a satisfactory control system based on detectors (flammable and other types).

Manufacturers have indicated that automatic self-diagnostic checks are useful and indeed are performed on certain types of instrument: existing infrared sensors use a standard absorber to simulate gas for continuously checking calibration. A gas-less auto-calibration would however be difficult for catalytic sensors which require a dose of gas. A gas-less auto-calibration system may possibly be useful for oil rigs or other applications where sites may be extremely inaccessible. Certainly offshore, catalytic sensors are being replaced by infrared and acoustic detectors which can perform some form of self-check without the need for gas. Even if a gas dosing system was set up, the automatic calibration system would itself have to be checked regularly. Also companies may not want additional sources of flammable material, e.g. gas bottles of calibration gas, on site which could create additional risk and discharge into the atmosphere.

Finally, it should be noted that substitution is the best form of risk reduction. Some companies are in the process of replacing organic solvents by water-based ones (which still however contain some organic solvents) to reduce volatility and avoiding costly explosion protection, flame proofing, etc.

One of the recommendations from Phase 1 was to consult more SMEs in the second phase of the project and possibly a few other larger user applications to cover as wide a cross-section of users as possible. Considerable difficulty was experienced in identifying suitable firms to visit, despite numerous requests to other parts of HSE for suggestions for firms to visit. With considerable effort being expended on trying to set up visits, but with little success it was decided to curtail the number of planned visits. The outcomes of the visits that were made, together with discussions during the consultations on likely firms to visit did, however, reinforce the findings detailed above.

It is, therefore, recommended that the HSE Guidance should be restricted to providing general advice on the use of gas detectors. This should be developed in consultation with industry user groups, user trade associations and CoGDEM, the gas detection manufacturers trade association. The guidance should also cover the three uses of gas detectors identified on the visits:

- fixed - built into equipment (process control and safety)
- fixed - general area monitoring (leak detection)
- portable - personal monitoring, used by contractors on-site, factory 'walk-through' surveys by the safety engineer, etc.

The HSE guidance should address general issues relating to these three uses of gas detectors. It should refer to existing standards e.g. BS EN 50073, to avoid duplication, and cover the following principal issues:

- installation
- types of sensor
- sensor location
- alarm levels - set points and how many (need to consider false alarms and adequate limit of detection)
- response time (linked to alarm levels)
- actions on alarm (depends on alarm level/importance/severity of harm)
- maintenance/calibration/response factors/function check
- other issues, e.g. intrinsic safety (IS) and functional safety of electrical/electronic/ programmable electronic safety-related systems.

The development of industry specific guidance, e.g. that produced by trade associations, in consultation with HSE, should be encouraged. This would compliment the general advice that would be given in the HSE Guidance Note.

3. SOURCES OF INFORMATION

3.1. Introduction

The original HSE guidance on flammable gas detectors (Guidance Note CS1) was withdrawn several years ago (HSE, 1987). It was out of date and much of the information can be found in BS EN 50073. However, our survey of users (Walsh et al, 1999) found a need for HSE guidance on this topic.

There are several sources of information that need to be considered when developing HSE guidance for gas detectors. This is to ensure that there is no unnecessary duplication in HSE guidance of material from these sources. Further information from these sources, which provides more detail or more background would then be available to the reader of HSE guidance through cited references. A summary of guidance relating to gas detectors is given in the Phase 1 report (Walsh et al, 1999) which itself was an update of earlier work (Walsh, 1998). The principal guidance is the BSI Guide for the selection, installation, use and maintenance of apparatus for the detection and measurement of combustible gases or oxygen (BSI, 1999). This is summarised in Section 3.2.

User industry guidance, either from trade associations, industry groups or individual user companies, will be the most specific. It is important that HSE guidance advises users to first look at any guidance that is specific to their industry or particular use. A listing of known industry group/trade association guidance that is available in the public domain is given in Table 2.5 of Walsh et al (1999). The development of such specific guidance should be encouraged. Gas detection equipment suppliers often supply guidance that obviously can only be general.

Since the Phase 1 report (Walsh et al, 1999) was published two new documents have been published: the BSI standard on dryers and ovens in which flammable substances are released and the COGDEM Gas Detectors and Calibration guide. These are summarised in Sections 3.3 and 3.4 respectively.

3.2. BS EN 50073:1999 Guide for the selection, installation, use and maintenance of apparatus for the detection and measurement of combustible gases or oxygen

This standard code of practice (BSI, 1999) is the principal source of general guidance on flammable gas and oxygen detectors. The scope of BS EN 50073 is instruments for detection and measurement of combustible gases as described in performance standards for point gas detectors BS EN 50054-58 (to be superseded by BS EN 61779-1, -2, -3, -4, -5) and oxygen in BS EN 50104. It does not cover, however, apparatus intended only for process control (see 4.2) and open path apparatus not used for point measurement (see 4.4.2). The guidance is intended for users with some specialist knowledge. A list of contents of BS EN 50073 is given in Appendix A, section A1.

3.3. BS EN 1539:2000 Dryers and ovens, in which flammable substances are released - Safety requirements

Dryers and ovens which generate flammable vapours are widespread and common throughout the UK and Europe. This standard (BSI, 2000) which details their safety requirements, has now been published. However, there is some controversy about the requirements for gas monitoring systems (Annex C.3) where 'the time T_{90} of the gas monitoring system including the whole sampling line shall be $\leq$ 1.5 s unless it is proved that a gas monitoring system with a longer time T_{90} could register the expected changes of concentration without permitting a hazardous state to occur'. The previous draft prEN1539 stated 'the time T_{90} of the detector shall be $<$ 1.5 s unless it is proved that a gas monitoring system with a longer time T_{90} could register the expected changes of concentration without permitting a hazardous state to occur'. This requirement is currently impossible to achieve, a response time of 1.5 s for the detector is difficult to attain even excluding the sampling line which will incur further delay. There is an ongoing discussion on how to resolve this matter.

3.4. The CoGDEM Gas detection & Calibration Guide

The CoGDEM Gas detection & Calibration Guide (CoGDEM, 1999) is a useful document for background information on gas detectors, especially their calibration, and certain aspects are suitable for the non-specialist. A list of contents of the CoGDEM guide is given in Appendix A, section A2. The guide is available to anyone and can be purchased through the CoGDEM website (cost approximately £50). The objective of the guide is to provide generic information on the principles of gas detector calibration and it is advised to use it in conjunction with the instrument manufacturer's specific instructions or maintenance schedule. It is probably too detailed for users when describing the measurement techniques; the section on calibration is again probably too detailed for a user but provides good background material. There is no discussion of selection and installation criteria and how to use the instrument - this is presumably left to the manufacturer or other guidance or standards. HSE guidance would therefore only overlap on any discussion of measurement techniques and calibration; this would not be significant.

4. PRINCIPAL ISSUES FOR HSE GUIDANCE

4.1. Introduction

The form of any HSE guidance on use of gas detectors would be necessarily general and aimed at users. It would provide the user with basic information on what to discuss with an equipment supplier about the most appropriate system to use. This can be conveniently summarised to focus discussion about the various principal issues which need to be considered when using any type of gas detection system (see below). In the HSE guidance, these issues may be further reduced in the form of an aide-memoire.

The BS EN 50073 guide text should be used whenever appropriate, possibly abbreviated. However, it should be noted that the BS EN 50073 guide does not cover process monitoring (see section 4.2) and open path detectors (see section 4.4.2).

The guidance itself should contain an Introduction, as in CS1 (HSE, 1987) for example, which provides the background to the subject matter and places it in the context of risk assessment. The other, more technical sections of the guidance are now briefly discussed.

4.2. System selection and specification

The user and the gas detection equipment supplier need to discuss the application. The gas detection equipment supplier may be:

- the equipment (incorporating gas detection instruments) supplier or instrument manufacturer themselves,
- their agent, or
- a system house for the more complex systems.

The user will have knowledge of the process, but probably not of gas detection while the reverse will tend to be true for the equipment supplier. A specification for the system will be the output of this discussion.

In developing the specification, both parties should be aware of the following factors that may form part of the specification, either explicitly or implicitly.

4.3. Types of monitoring applications

Refer to BS EN50073 Clauses 1 and 4 for further details.

There are two basic reasons for using gas detecting systems in industrial environments. The first is to ensure the safety of personnel and plant by giving warning of dangerous conditions caused by the gas of interest. The second reason is for the purposes of process monitoring and control, e.g. product quality control or for the control of releases into the workplace and environment.

There are three types of application where gas monitoring instruments are used in industrial environments for safety purposes:

1. Online process safety monitoring, where the detectors are built in to the process or plant at the design stage. The purpose is for process safety control with alarms for adverse conditions and possibly coupled with executive action, e.g. oxygen monitoring and inerting.

2. Fixed installation in the workplace for area monitoring , where a particular location is at risk from a leak of gas or vapour. In this type of situation fixed site monitors are appropriate. The location could be monitored to protect personnel, to prevent fire and explosion or for environmental reasons. Multiple detectors are normally used with the outputs connected to a single control and monitoring location. Single detectors with alarms are also possible.

3. Personal and portable (e.g. hand-held) monitoring where an individual worker or a group of workers use personal or portable gas monitoring instruments to provide early warning protection against a hazard caused by a gas or gases. Common examples are entry into confined spaces and hotworking.

All three types of usage should be covered by the HSE guidance.

4.4. Principles of sensor operation

4.4.1. Detection techniques

Refer to BS EN50073 Clause 5 and Annex A for further details.

Tables 1 and 2 give a summary of the operating principle of common detector systems and a guide to the advantages and disadvantages of each. More detail is available in other publications (e.g. BS EN 50073 Annex A, CoGDEM Gas Detection & Calibration Guide).

The principal techniques currently used in industry for flammable gas detection are catalytic, infrared (point and open-path) and flame temperature/ionisation. The difference between point gas detectors and open-path detectors is described in 4.4.2. For oxygen deficiency and enrichment measurement, the principal techniques are paramagnetic, electrochemical (liquid electrolyte) and zirconia (solid electrolyte). In addition to the above concentration-based detection methods, the use of ultrasonic (acoustic) detectors is increasing, particularly offshore. These are not based on measurement of gas concentration but on a gas leak property (see 4.4.3).

4.4.2. Point and open-path infrared flammable gas detectors

Point gas detectors measure the concentration of gas at the sampling point of the instrument. The units of measurement are typically % volume ratio, %LEL for flammable gas, ppm for low level concentrations and toxic gases, or more rarely mg/m^3.

Open path detectors, also known as beam detectors, typically consist of a radiation source and a physically separate, remote detector that measures the concentration of gas integrated along the path of the beam. The path can vary from several metres to a few hundred meters. This allows the monitor to cover large distances. The basic units of measurement are concentration x length, for example %LEL.m or ppm.m. The open-path technique is incapable of distinguishing a high concentration over a short distance and a lower concentration distributed over a longer distance if they give the same reading. Open-path monitors require care when interpreting the readings, as they are not in units of say %LEL, the pathlength needs to be taken into account. However, alarms can be set based on their particular application through discussions between the supplier and the user, for example. This is commonly done offshore and on large plants onshore.

No BSI standard for guidance on their use (i.e. an equivalent to BS EN 50073 for open-path monitors) has been produced as yet. Only performance standards (BS EN 50241-1 and 50241-2) exist for flammable gas measurement.

4.4.3. Ultrasonic leak detectors

Ultrasonic or acoustic gas detectors detect leakage of high pressure gas through an orifice by measurement of the ultrasound emitted. They are not concentration based, therefore careful interpretation of the readings is required to obtain meaningful measurements. Nevertheless, all the considerations in subsequent sections also apply to ultrasonic detectors. If suitable alarm levels are set, they can provide an alternative method of leak detection where high pressure gas systems are in use. Their advantage, assuming careful siting, is that gas is not required to be transported to the detector as is required for point and open-path concentration based detectors (see 4.6 Location).

Table 1 - Flammable gas detectors

POINT DETECTORS				
Sensor Type	**Principle of Operation**	**Usage & Range**	**Advantages**	**Disadvantages**
Catalytic	Heat is generated during the catalysed reaction between a fuel gas and oxygen in air. This creates a temperature rise in the catalytic bead ('pellistor') causing a change in electrical resistance. The change in resistance is a measure of gas concentration.	Flammable gases from 0 to 100% LEL	Small size.	Needs oxygen > 10%. Slow response. Ambiguous readings above UEL - needs failsafe. Can be poisoned.
Infrared	Absorption of infrared light by certain molecules is detected by attenuation over a short beam path.	Mainly hydrocarbon vapours from 0 to 100% v/v	Oxygen not needed. Unambiguous above LEL. Not poisoned.	Pressure sensitive. Cannot detect hydrogen.
Flame Temperature	The temperature of a controlled hydrogen flame is monitored 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.	Flammable gases from 0 to 100% LEL	Fast response.	Needs a hydrogen and a clean air supply. Large size. Halon may cause a misreading.
Flame Ionisation	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 in the ionised gas is measured. The source of ionisation is a hydrogen flame.	Most hydrocarbon gases and vapours from sub-ppm to %v/v	Fast response Sensitive	Needs a hydrogen and "clean" air supply.
Photoionisation	A similar principle to the flame ionisation detector, but the source of ionisation is an ultraviolet lamp.	Dependent on the energy of UV lamp. Range from ppm to %v/v	Fast response Sensitive. Used as sensitive hand-held leak detectors	Humidity may affect readings.

Thermal Conductivity	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 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.	0.1% v/v to 100% v/v	Can be used to compensate catalytic detectors when they are used above the UEL.	Works well only when differences in thermal conductivity between target gas and reference (air) are large, eg hydrogen, methane.
Semiconductor	A surface interaction between 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.	Most hydrocarbon gases and vapours from ppm to %v/v		Non-linear Can be poisoned. Needs oxygen. Water vapour sensitive. Sensitive to many gases/vapours.

OPEN-PATH (BEAM) DETECTORS

Sensor Type	Principle of Operation	Usage & Range	Advantages	Disadvantages
Infrared	Similar to infrared point sensors. The source of infrared light is a powerful narrow beam that illuminates the space between source and detector. Gas can be detected anywhere in this line of sight.	Mainly hydrocarbon vapours from 0 to 100% v/v	Large spaces can be easily monitored.	Objects in the beam path can give false readings. Solar interference can be a problem. Alignment of source and detector requires great care.

NON-CONCENTRATION BASED DETECTORS

Sensor Type	Principle of Operation	Usage & Range	Advantages	Disadvantages
Ultrasonic	Escape of gas from a pipeline under high pressure or other pressurized system generates ultrasound which can provide a measure of the leak rate.	Leaks from high pressure systems.	Theoretically provides 360 ° coverage and does not require transport of gas to detector.	Care needed in placement. False alarms from other ultrasonic emissions.

Table 2 - Oxygen detectors

POINT DETECTORS				
Sensor Type	**Principle of Operation**	**Usage & Range**	**Advantages**	**Disadvantages**
Electrochemical	The gas diffuses through a permeable electrode to its interface with the cell's electrolyte. Electrochemical reactions take place here that alter the electrical characteristics of this electrode. Measurement of these electrical parameters with respect to other electrode(s) within the cell give a signal proportional to the gas concentration.	Oxygen from 0 to 100% (Toxic gases from 0 to 1000 ppm)	Small size Low power	Slow response
Paramagnetic	Oxygen atoms are paramagnetic. Paramagnetism is a phenomenon where molecules are strongly attracted to a magnetic field. Measuring the differential interaction between the magnetic field and the target gas and reference gas generates a response proportional to the oxygen concentration.	0 to 100%	Fast response	Orientation dependent.
Zirconia-type	Zirconium oxide (zirconia) or similar substances are ceramics that conduct electricity by the movement of oxygen ions when heated above 300° C. If the oxygen concentration on each side of a thin flat plate of zirconia is different, a flow of ions 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.	ppb v/v to % v/v	Suitable for high temperature environments. Very sensitive.	Non-linear response Temperature dependent response.

4.5. Installation

This is of course only applicable to online process and fixed systems. Refer to BS EN50073 Clause 6.2 for further details.

4.6. Detector location

This applies to fixed area monitoring only. The effective operation of a gas detection system for area monitoring relies critically on the placement of the detectors. Refer to BS EN50073 Clause 6.3 for further details. The current guidance in this standard is as good as there is for general advice. There is, however, a distinct lack of specific guidance on this subject. Offshore platforms adopt a rule of thumb for placement of flammable gas detectors at 5 m intervals (UKOOA, 1995) based on studies of flame velocities and overpressures which did not cause significant damage when flame fronts were less than 6 m (HSE, 1993). The effectiveness of this 'guidance' and optimisation of gas detector location was investigated in detail by HSL using data from natural gas releases on a simulated offshore platform (Kelsey et al, 2000a; Kelsey et al, 2000b). CFD studies of gas dispersion in gas turbine halls have also been carried out which have led to guidance on placement of detectors and higher performance flammable gas sensors (Lewis, 2000). Similar studies could be devised for other common or critical applications: analysis of gas dispersion and gas detectability from fullscale or third-scale practical experiments.

4.7. Response time

Refer to BS EN50073 Clause 4.7 and Table 1 for further details.

In gas detector specifications the response time is usually defined as the time it takes for the output of the sensor to reach 90% of its final value when subjected to a step change in gas concentration at its sampling point. It is often written in the form T_{90}. Other definitions are also used e.g. T_{95}, T_{50}. The overall response time of a gas sensing system is governed by two factors:

- The intrinsic response time of the gas sensing mechanism of the sensor. This is determined by, for example, chemical reaction rates (e.g. in the catalytic sensor), or physical changes (e.g. spectrocopic transitions for infrared).

- The time taken to transport the sample to the sensor. For aspirated (pumped) systems, used to sample remotely or to give a fast response, the transport time is determined by the sample tube length, the sample tube diameter, the aspiration rate and the rate of diffusion from the flow system into the sensor. For non-aspirated (diffusive) systems only diffusion to the sensor occurs.

A decision on an acceptable response time for a detector system will depend on the location and purpose of the system. The response time of the detector should be matched to the speed of the expected problem. Protection of personnel, large or catastrophic leaks, control or monitoring of fast acting processes all require detectors with a fast response time. Detection of small leaks that build up gas concentration slowly, slow processes and non-toxic environmental monitoring can accept a much slower response. The response time should be considered in conjunction with the detector location and alarm level.

Again, as with location, there are no specific rules. The relationship between gas detector location, response time and alarm levels has not been explored in any detail. Guidance is currently limited to 'rule of thumb' and 'best practice', none of which would probably stand up to rigorous examination. There is scope for attempting to define these inter-relationships for various release scenarios in more detail through simulations and practical tests.

4.8. Alarm levels

Refer to BS EN50073 Clause 6.4.1 (fixed) and 7.2 (portable) for further details.

Risk factors must also be taken into account when setting alarm levels. The level will depend on the degree of risk associated with the alarm and its potential consequences.

Most commercially available gas detector systems have one or more user selectable alarm levels. The setting of the alarm level must take a number of factors into account. It is desirable to set the first alarm level as low as possible, but this level must be high enough to avoid false alarms. False alarms are most likely to be caused by variations in the sensor output due to environmental changes such as ambient temperature, pressure and humidity, and cross-sensitivity to other gases/vapours, other causes may be dust or other contamination, electromagnetic interference and ageing of the sensor or electronics, resulting in drift over short or long periods. The upper level of the alarm must be commensurate with the risk and consequences of that amount of gas being released.

The response time of the detector system, together with the position and distance from the leak are also factors to take into account when setting alarm levels. A slow detector system with a low alarm level positioned close to a leak can be just as effective in some circumstances as a fast system with a higher alarm level placed further from the source of the leak. Obviously this assumes that the leak location is known with a high probability. The presence of valves, flanges in gas pipelines etc. are known sources of leaks.

For safety critical applications an alarm for fault conditions of the detector is vitally important. There are some situations where a failure of some part of the detector systems could continue to show a zero reading, falsely indicating a safe position. Ideally, the detector should not have non-detectable fault conditions.

4.9. Actions on alarms

Refer to BS EN50073 Clause 8.1 for further details. There must be clear instructions for appropriate personnel on what to do when any alarm sounds or when an executive action is activated by a detector alarm occurs. This must be backed up by suitable training and refresher courses. These instructions should be linked to safety procedures and the company safety management system.

Flammable gas detector control panels with attendant alarms can be co-located with fire detection systems. The actions on alarm may be very different depending on whether there is a release of gas or a fire is detected.

4.10. Calibration and Maintenance

It is extremely important to have an inspection (function check), calibration and maintenance routine. Here, inspection is defined as in BS EN 50073 Clause 6.4.2 while calibration and maintenance are described in BS EN 50073 Clause 6.4.3. Detector performance is affected by operational life and the initial accuracy upon commissioning will degrade depending on the type of detector and operating conditions. These checks and calibrations should form part of a Quality Management System.

Refer to BS EN50073 Clauses 6.4, 7 and 8 for further details. The CoGDEM Guide also has useful information on calibration.

A gas mixture from a cylinder is the most common, convenient and accurate means of calibrating fixed site or online process gas detectors. Other methods are available, but these are more normally found in laboratory situations.

In many cases, however, obtaining a calibration gas mixture in a cylinder is a physical impossibility. Many organic solvents will produce a flammable mixture in air at ambient temperature and pressure, but become liquids when pressurized in a gas cylinder. In these circumstances calibration with another gas mixture is possible. The mixture must be selected to give a similar detector response to the target gas. The difference in the detector output is then corrected by use of a response or calibration factor and most detector manufacturers have tables that show the appropriate calibration gas mixture and the correction factor for every target gas that the sensor will respond to.

Many gas sensors are sensitive to pressure and care must be taken when calibrating instruments that true readings are produced. When using a gas mixture cylinder to calibrate a diffusion type instrument it is normal to pass the gas through a calibration mask and out to atmosphere. Excessive flow through the calibration mask must be avoided as this will lead to over pressuring the sensor and false readings. If the flow is too low air can diffuse back into the mask and again give false readings. This is normally only a problem for very low level gas concentrations. For aspirated instruments it is normal to flow the gas mixture to waste and allow the instrument to draw the mixture from a tee-piece or a reservoir in the line. Again care must be taken not to set the flow too high or too low. An excessive flow can cause the sensor to be over pressurised and an insufficient flow can be diluted by air being drawn into the calibration system by the instruments pump. On aspirated systems care must be taken to ensure that all joints in the sampling system are secure. A loose joint will allow air to be drawn in, dilute the sample and give a lower reading on the instrument. In all cases care must be exercised over the waste calibration mixture if it is released into an enclosed space. It is unlikely to build up to a flammable level, but with some calibration mixtures the occupational levels set under COSHH (EH40) could be quickly exceeded.

4.11. Other issues

4.11.1. Explosion prevention and mitigation

Gas detectors are not currently considered reliable enough to depend upon as the sole means of explosion protection. They should, therefore, not be used as the safety critical protection system. Indeed, in all the companies visited for this project, gas detection was used in addition to a back-up safety system. However, whether this will continue to be the case is not certain. Usually the main protection system adopted was explosion prevention through intrinsic safety and/or explosion mitigation through explosion relief.

4.11.2. Functional safety systems

Flammable gas detectors may form part of a complex safety related system. In this case standard IEC 61508 'Functional safety of Electrical/electronic/programmable electronic safety-related systems' may be applicable. This standard sets out a generic approach for all safety lifecycle activities for systems comprised of electrical and/or electronic and/or programmable electronic systems (E/E/PESs) that are used to perform safety functions. However the standard does not cover E/E/PE systems where a single E/E/PES system is capable of providing the necessary risk reduction and the required safety integrity of the E/E/PE system is less than that specified for the lowest safety integrity level in the standard (level 1). Low complexity E/E/PE safety related systems may be exempt from compliance with certain requirements. Expert advice is required to decide whether a gas detection system could be exempt from these requirements.

4.11.3. ATEX Directives

EC Directive 94/9/EC: Equipment and protective systems intended for use in potentially explosive atmospheres (ATEX) regulates the technical requirements for all such equipment and protective systems. The directive itself describes the essential safety requirements in general terms. This directive also requires a type test for gas detection apparatus intended for use in zones 0 and 1. Equipment supplied for use in potentially explosive atmospheres must therefore have the 'CE' and 'Ex' markings to show conformity with the regulations.

There is also a new, additional ATEX directive (EC Directive COM (95) 310 (Draft) concerned with the implementation of the 'minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres'. This may also require testing of gas detection systems to conform with its essential safety requirements.

5. CONCLUSIONS AND RECOMMENDATIONS

1. The principal issues involved in developing HSE guidance for inspectors and users of gas detection equipment in process control and safety, fixed area monitoring and portable monitoring for personal protection have been summarised.

2. There is no BSI standard guide for the selection, installation, use and maintenance of open-path detectors (the equivalent of BS EN 50073:1999 for point gas detectors).

3. The information summarised in this report should be used as the basis of HSE guidance on gas detectors for internal use (for inspectors) and as a published HSE guidance document.

4. The development of guidance for specific applications by trade associations, user groups or indvidual companies should be encouraged.

5. The relationships between gas detector location, alarm level and response time should be explored through a combination of modelling and practical tests for common or critical applications of fixed gas detectors. This would generate more specific guidance on gas detector location which is currently lacking.

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7. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the many useful discussions with the companies and organisations listed below during the course of the project.

Analox Sensor Technology Ltd
Crowcon Detection Instruments Ltd
Field Packaging plc
General Monitors
ICI Chemicals & Polymers
IGD
J Rostron Engineering Ltd
Lubrizol International Laboratories
Orbital Gas Systems Ltd
Reckitt and Coleman
Sentinal Foams Ltd
The Council of Gas Detection and Environmental Monitoring (CoGDEM)
Vinamul
Zellweger Analytics

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A.2 COGDEM GAS DETECTION AND CALIBRATION GUIDE

Electrochemical
Liquid electrolytic fuel cells
Flame ionisation detector (FID)
Gas chromatography (GC)
Mass spectroscopy (MS)
Infra-red (IR) detectors
Paramagnetic oxygen analysers
Pellistor (catalytic bead)
Photo-ionisation detectors (PID)
Semiconductor
Thermal conductivity (TC)

CALIBRATION
Why is calibration necessary?
Methods of calibration
Flammable gases
Toxic gases
Errors
Calibration methods
Production techniques
Accuracy and traceability of gas mixtures
Preparation by mixing
Use of gas sample bags

CALIBRATION TECHNIQUES
Calibration methodology
Instrument specifications

MAINTAINING GAS MIXTURE QUALITY FROM THE CYLINDER TO THE INSTRUMENT
Leakage out
Gas control equipment
Pressure regulators
Flow control valves

GAS HANDLING
Safety and transportation issues with gas cylinders
Cylinder handling
Transportation of calibration gas cylinders
Return or disposal of refillable cylinders
Disposal of non-refillable cylinders

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