

Guide for selection, installation, use and maintenance of apparatus for the detection and measurement of combustible gases or oxygen

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National foreword

This British Standard is the English language version of EN 50073:1999. It supersedes BS 6959:1989 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GEL/31, Electrical apparatus for use in explosive atmospheres, to Subcommittee GEL/31/19, Gas detectors, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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Guide for selection, installation, use and maintenance of apparatus for the detection and measurement of combustible gases or oxygen

Guide de sélection, d'installation, d'utilisation et de maintenance des appareils de détection et de mesure de gaz combustible ou d'oxygène

Leitfaden für Auswahl, Installation, Einsatz und Wartung von Geräten für das Aufspüren und die Messung brennbarer Gase oder von Sauerstoff

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CENELEC

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Foreword

This European Standard was prepared by SC 31-9, Electrical apparatus for the detection and measurement of combustible gases to be used in industrial and commercial potentially explosive atmospheres, of Technical Committee CENELEC TC 31, Electrical apparatus for explosive atmospheres.

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1 Scope

This document gives guidance on the selection, installation, use and maintenance of electrically operated Group II¹⁾ apparatus intended for use in industrial and commercial safety applications for the detection and measurement of:

- combustible gases, as described in EN 50054, EN 50057, EN 50058; or
- oxygen as described in EN 50104.

This guide is a compilation of practical knowledge to assist the user. Combustible gas detection apparatus, fixed, transportable or portable, may be used whenever there is the possibility of a risk to life or property caused by the accumulation of a combustible gas-air mixture. Such apparatus can provide a means of reducing the risk by detecting the presence of the combustible gas and issuing suitable audible or visual warnings. It may also be used to initiate specific safety precautions (e.g. plant shutdown, evacuation, operation of fire extinguishing procedures).

It is applicable to all new permanent installations and, where reasonably practicable, to existing permanent installations. It is also applicable to temporary installations, whether new or existing.

This guide is not intended, but may provide useful information, for the following:

- apparatus intended for the measurement of oxygen deficiency which may affect human health;
- apparatus intended only for the detection of non-combustible toxic²⁾ gases;
- apparatus of laboratory or scientific type intended only for analysis or measurement purposes;
- apparatus intended for underground mining applications;
- apparatus intended only for process control applications.

This guide does not apply to the following:

- apparatus for the detection of explosives;
- apparatus intended for the detection of a potentially combustible atmosphere resulting from dust or mist in air;
- open path apparatus not used for point measurement.

2 Normative references

This European Standard incorporates by dated or undated references, provisions from other publications. These normative references are cited at the appropriate place in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 50014:1997, *Electrical apparatus for potentially explosive atmospheres — General requirements.*

EN 50015:1998, *Electrical apparatus for potentially explosive atmospheres — Oil immersion “o”.*

EN 50016:1995, *Electrical apparatus for potentially explosive atmospheres — Pressurized apparatus “p”.*

EN 50017:1998, *Electrical apparatus for potentially explosive atmospheres — Powder filling “q”.*

EN 50018:1994, *Electrical apparatus for potentially explosive atmospheres — Flameproof enclosure “d”.*

EN 50019:1994, *Electrical apparatus for potentially explosive atmospheres — Increased safety “e”.*

EN 50020:1994, *Electrical apparatus for potentially explosive atmospheres — Intrinsic safety “i”.*

EN 50028:1987, *Electrical apparatus for potentially explosive atmospheres — Encapsulation “m”.*

EN 50039:1980, *Electrical apparatus for potentially explosive atmospheres — Intrinsically safe electrical systems “i”.*

EN 50054:1998, *Electrical apparatus for the detection and measurement of combustible gases — General requirements and test methods.*

EN 50057:1998, *Electrical apparatus for the detection and measurement of combustible gases — Performance requirements for Group II apparatus indicating up to 100 % lower explosive limit.*

EN 50058:1998, *Electrical apparatus for the detection and measurement of combustible gases — Performance requirement for Group II apparatus indicating up to 100 % (V/V) gas.*

EN 50104:1998, *Electrical apparatus for the detection and measurement of oxygen — Performance requirements and test methods.*

EN 60079-10:1996, *Electrical apparatus for potentially explosive atmospheres — Part 10: Classification of hazardous areas.*

IEC 60079-20, *Electrical apparatus for explosive gas atmospheres — Part 20: Data for flammable gases and vapours, relating to the use of electrical apparatus.*

¹⁾ Group II apparatus are suitable for places with potentially explosive atmospheres, other than mines susceptible to firedamp, see 4.3.

²⁾ For the purpose of this guide, “toxic” covers “toxic”, “very toxic” and “harmful” gases and vapours.

3 Definitions

For the purpose of this standard the following definitions apply.

3.1

type of explosion protection

the measures applied in the construction of electrical apparatus to prevent ignition of a surrounding explosive atmosphere by such apparatus (see 4.3)

3.2

lower explosion limit (LEL)

the volume ratio of combustible gas or vapour in air below which an explosive gas atmosphere will not be formed

3.3

upper explosion limit (UEL)

the volume ratio of combustible gas or vapour in air above which an explosive gas atmosphere will not be formed

3.4

explosive gas atmosphere

a mixture with air, under normal atmospheric conditions, of combustible gases or vapours, in which, after ignition, combustion spreads throughout the unconsumed mixture

3.5

Group II apparatus

electrical apparatus for places with a potentially explosive atmosphere, other than mines susceptible to firedamp (see 4.3)

3.6

firedamp

a combustible gas, consisting mainly of methane, found naturally in mines

3.7

fixed apparatus

an apparatus which is intended to have all its parts permanently installed

3.8

transportable apparatus

an apparatus not intended to be portable, but which can be readily moved from one place to another

3.9

portable apparatus

spot reading or continuously sensing apparatus designed to be readily carried from place to place and to be used whilst being carried. Portable apparatus with integral or separate battery includes, but is not limited to:

- hand-held apparatus, typically less than 1 kg, suitable for single-handed operation;
- personal monitors, similar in size and mass to the hand-held apparatus, that are continuously operating (but not necessarily continuously sensing) whilst attached to the user; and
- larger apparatus up to 5 kg that can be operated by the user whilst suspended by hand, by a shoulder strap or by a carrying harness; it may or may not have a hand directed probe.

3.10

spot reading apparatus

an apparatus intended to be used for short periods of time as required

3.11

continuous duty apparatus

apparatus which is continuously powered but may have continuous or intermittent sensing

3.12

sensor

an assembly in which the sensing element is housed that may contain associated circuit components

3.13 sensing element

that part of a sensor that reacts in the presence of a combustible gas mixture to produce some physical or chemical change that can be used to activate a measuring or alarm function, or both

3.14

catalytic sensor

a sensor, the operation of which depends upon the oxidation of gases on an electrically heated catalytic element (see A.1)

3.15

thermal conductivity sensor

a sensor, the operation of which depends upon the change of heat lost by conduction of an electrically heated element located in the gas to be measured, compared with that of a similar element located in reference gas cell (see A.2)

3.16

infra-red sensor

a sensor, the operation of which depends upon the absorption of infra-red radiation by the gas being detected (see A.3)

3.17

open path infra-red sensor

a sensor that is capable of detecting gas at any location along an open path traversed by an infra-red beam

3.18

semi-conductor sensor

a sensor, the operation of which depends upon changes of the electrical conductance of a semiconductor due to chemisorption of the gas being detected at its surface (see A.4)

3.19

electrochemical sensor

a sensor, the operation of which depends upon changes of the electrical parameters of electrodes placed in an electrolyte due to redox reactions of the gas on the surface of the electrodes (see A.5)

3.20

flame ionization detector (FID)

a sensor, the operation of which depends upon the ionization of the gas being detected in a hydrogen flame (see also A.6)

3.21

flame temperature analyser (FTA)

a sensor, the operation of which depends upon the change of temperature of a flame by the gas being detected (see also A.7)

3.22

photo ionization detector (PID)

a sensor, the operation of which is based on the ionization of gaseous compounds by ultraviolet (uv) radiation (see also A.8)

3.23

paramagnetic oxygen detector

a sensor, the operation of which depends upon the magnetic properties of the gas being detected (see also A.9)

3.24

continuous or quasi-continuous sensing

a mode of operation in which power is applied continuously to the sensing element

3.25

intermittent sensing

a mode of operation in which readings are taken according to a predetermined cycle

3.26

remote sensor

a sensor which is not integral with the main body of the apparatus

3.27

single point sensor

a sensor which is capable of detecting gas at a single point location

3.28

aspirated apparatus

apparatus which obtains the gas by drawing it to the gas sensor, for example, by means of a hand operated or electric pump

3.29

diffusion apparatus

apparatus in which the transfer of gas from the atmosphere to the gas sensing element takes place by diffusion, i.e. there is no aspirated flow

3.30

sampling line

the pipeline by means of which the gas being sampled is conveyed to the sensor including accessories (e.g. filters)

3.31

sampling probe

a separate sampling line that may or may not be supplied with a portable apparatus, that is attached to the apparatus as required

3.32

ambient air

the normal atmosphere surrounding the apparatus

3.33

clean air

air that is free of combustible gases, and interfering contaminating substances

3.34

alarm setpoint

a fixed or adjustable setting of the apparatus that is intended to pre-set the level of concentration at which the apparatus will automatically initiate an indication, alarm or other output function

3.35

drift

the variation in apparatus indication with time at any fixed gas volume ratio (including clean air) under constant ambient conditions

3.36

source of release

a point of location from which a combustible gas, vapour or liquid may be released into the atmosphere such that an explosive gas atmosphere could be formed

3.37

release rate

the quantity of combustible gas or vapour emitted per unit time from the source of release which itself could be a liquid surface

3.38

ventilation

movements of air and its replacement with fresh air due to the effects of wind, temperature gradients, or artificial means (e.g. fans or extractors)

3.39

relative density

the density of gas or vapour relative to the density of air at the same pressure and at the same temperature (air is equal to 1,0)

3.40

flash-point

the lowest liquid temperature at which, under certain standardized conditions, a liquid gives off vapours in a quantity such as to be capable of forming an ignitable vapour/air mixture

3.41

volume ratio (V/V)

ratio of the volume of a component to the volume of the gas mixture under specified conditions of temperature and pressure

3.42

dose

the total amount of substance absorbed or trapped, proportional to the concentration and the duration of exposure

3.43

initial calibration

the first calibration for a specific substance, measuring range and application carried out by the manufacturer before delivery or on site before starting the operation

3.44

recalibration

further calibrations carried out periodically to check and adjust the zero signal and the sensitivity of the sensor with a known calibration gas mixture without any changing of the parameters, type of gas, measuring range, specific application, which have been established by the initial calibration

3.45

field check with gas

the application of test gas on the sensor to check the response signal or generating of alarm without adjusting zero signal and sensitivity

3.46

response time

the time interval between the time when an instantaneous increase in gas concentration is produced at the sensor input and the time when the response reaches a stated indication

3.47

recovery time

the time interval between the time when an instantaneous decrease in gas concentration is produced at the sensor input and the time when the response reaches a stated indication

4 Intended application

4.1 General

The physical principles of detection are defined in clause 3 and explained in detail in annex A. Guidance for operation of the most common types of sensors used in apparatus for the detection of combustible gases or oxygen covered by this guide are described in 5.2 to 5.10.

NOTE It is not intended, by means of this guide, to discourage the use of apparatus using detection principles other than those described in 5.2 to 5.10 or to inhibit the development of new detection principles. However, it is of primary importance that the capabilities of the detection principle should be such that the performance of the apparatus is adequate for the intended application. Assessment of the apparatus against the performance requirements specified in EN 50054, EN 50057, EN 50058 and EN 50104 may provide a basis for judgement in appropriate circumstances.

It is normally not possible to determine the concentration of an individual combustible gas within a mixture of combustible gases using the type of apparatus covered by this guide. In general, most of the sensors described in this guide respond to all of the combustible components of a mixture, without discrimination.

When a mixture of gases of known relative concentration is to be monitored, it is recommended that this mixture is used for calibration. When the composition of a mixture is unknown or if a range of gases are likely to be present in the area to be monitored, it is recommended that the sensor is calibrated to the gas to which it is least sensitive.

Measurement of oxygen in relation to explosion protection is necessary to:

- ensure the minimum oxygen concentration for correct functioning of apparatus for the detection and measurement of combustible gases and vapours;
- ensure the maximum oxygen concentration in inertisation;
- monitor any increase in oxygen concentration which may increase the upper explosion limit and may decrease the energy required for ignition.

The lower and upper explosive limits of combustible gas in air will vary with temperature, pressure and oxygen concentration. Normal variations in the ambient conditions should not significantly affect the performance of the apparatus. However, if larger variations of temperature or pressure are expected, the manufacturer should be consulted, see also annex D.

According to the specific application, the suitability of the whole system has to be assessed, including the selection and placement of sensors, the alarm levels and response time. It may be appropriate to obtain advice from equipment manufacturers or a suitably trained person.

For apparatus for the detection of combustible gases and oxygen there are two independent categories of test.

- Performance test: to ensure that devices are suitable for the detection of those gases and ranges they are designed for.
- Electrical test: to prevent the ignition of explosive atmospheres by the apparatus itself.

NOTE The EU Directive 94/9/EC covers certification including both categories of test.

4.2 Performance testing

It is recommended that the performance of the apparatus is tested in accordance with EN 50054, EN 50057, EN 50058, EN 50104 or other accepted methods and that the test results are considered for the intended application.

4.3 Electrical testing and certification for use of apparatus in potentially explosive atmospheres

For the use of apparatus in potentially explosive atmospheres, it is a requirement that electrical testing and certification is in accordance with EN 50014 to EN 50020, EN 50028 or EN 50039 or any other type of protection accepted for Group II apparatus.

NOTE Apparatus is required to be endorsed with the “Ex” or “EEx” marking.

The certification is not valid in oxygen enriched atmospheres for example, welding gas mixtures.

4.4 Fixed apparatus and fixed systems

The operation of fixed systems is described in clause 6.

Fixed apparatus should be used where permanent gas monitoring in selected areas of a plant or other installation is required. These areas may be static as in manufacturing plant or mobile as in transport systems.

The use of a battery back-up system will increase the availability of the apparatus.

The three main types of fixed apparatus in common use are.

- 1) Apparatus having sensor and control unit situated within the hazardous area. The sensor and control unit may be combined or supplied as separate items.

- 2) Apparatus having sensors separate from the control unit. This type of apparatus usually consists of individual sensors in the hazardous area, connected to the associated control unit which is outside the hazardous area. This is the most common type for the majority of industrial applications.

- 3) Sampling apparatus. This type of apparatus usually has one or more sampling points in the hazardous area, each point connected to the sensor by means of an aspirated sampling line.

Fixed apparatus and systems described here should not be confused with those for process control, which are not covered by this guide.

4.5 Transportable apparatus

The operation of transportable apparatus is described in clause 7.

Transportable apparatus should normally be used for such purposes as monitoring temporary work areas (“hot” work) and areas where combustible liquids, vapours or gases may be transferred.

Care should be taken to avoid condensation in the apparatus and sampling line especially when an apparatus is transferred to an environment with a different ambient temperature.

4.6 Portable apparatus

The operation of portable apparatus is described in clause 7.

Portable apparatus should normally be used for such purposes as leak seeking, verification of combustible gas-free conditions, safety checks and similar applications.

Portable apparatus is normally used in diffusion mode, but where leak seeking is involved or where the apparatus is used for the detection of combustible gas in confined spaces beyond the normal reach of the user, either a static probe or a hand or mechanically aspirated sampling probe will be necessary.

4.7 Sampling lines and sampling probes

Sampling lines are usually permanently installed in fixed installations. Sampling probes are associated with transportable and portable apparatus, are usually short (in the order of 1 m) and rigid, however, they may be telescopic and may be connected to the apparatus by a flexible tube.

Consideration should be given to the effects of condensation occurring with water and high flash point liquids on sampling systems, since condensation may block the sampling line, lower the concentration and hence the reading and may contaminate following samples. To minimize this effect a heating of the sampling line may be necessary; in hazardous areas this heating system shall comply with the relevant regulations, see EN 50014 and related standards.

The material of the sampling line(s) should be selected so as to avoid adsorption or absorption of the gas being detected.

Sampling lines should be as short as possible since the response time is determined by the overall length. In addition, care should be taken to avoid dilution of the sampling by leakage or diffusion of dilutant air, or gas, into the sampling line or combustible gas out of the sampling line.

The flow rate through the sampling line should be monitored.

4.8 Filters

Filters may be used to protect the apparatus from dust and interfering or poisoning substances. Filters may increase the response time.

Humidity and/or condensation may completely block the filter pores.

The lifetime of filters is dose dependent (dust or interfering substance). This may shorten the maintenance intervals of the apparatus. For details refer to the instruction manual.

4.9 Flame arrestors

Some applications require flame arrestors, for example, sintered metals, capillary holes, gaps, for operation. These devices may increase the response time, may be affected by corrosion and may be blocked by dust or condensation.

Flame arrestors are especially used when sampling lines pass from a hazardous to a non-hazardous area. Additionally, mounted flame arrestors should be checked to confirm that they are suitable for their application.

5 Criteria of selection

5.1 General

The following criteria are among those which should be considered when selecting appropriate gas detection apparatus.

- The gas(es) which the apparatus is required to detect.
- The range of concentrations which may be encountered.
- The presence of potentially interfering gases.
- The intended application of the apparatus; e.g. area monitoring, personal safety, leak seeking, or other purposes.
- The required explosion protection for the area(s) of use, see 4.3 and EN 60079-10.
- The environmental conditions of the area(s) of use and a comparison of the requirements with the data of the manufacturer (instruction manual).
- The time to alarm for the whole system which includes:

- delay time of the sampling system;
- response time of the sensor;
- delay time of alarm devices and switching circuits.

The time to alarm should be compatible with the specific application.

h) The type of apparatus; fixed, transportable, or portable. For details, advantages, and restrictions of the three types see clauses 6 and 7.

i) The type of sampling system; diffusion or aspirated. For details and restrictions of both types see 4.7 to 4.9 .

j) The materials of the sensors and housings and their compatibility with the anticipated operating environment (corrosives; wind, rain, hosing etc.).

Whatever type of sensor is selected, errors may result if:

- the apparatus is used to detect gases for which it is not calibrated;
- the gas sample is not conditioned to remove water vapour or other interfering vapours or gases, some of which may result in a negative response;
- variations in ambient conditions (without compensation) influence the response of the specific sensor type.

Table 1 gives an overview of the most common principles which are explained in more detail in 5.2 to 5.10. See annex A for the detailed physical definitions.

5.2 Catalytic sensor

The following clauses give some typical information for this sensor-type. This information is additional to the general information given in clauses 4 and 5.1.

5.2.1 Common applications

The sensor is suitable for:

- the detection of a wide range of flammable gases;
- the detection of gas/air mixtures up to the lower explosive limit (LEL).

Sensor enclosures incorporate a permeable sintered metal device to allow gas to reach the sensing element and to ensure that gas ignited by the hot sensing elements does not ignite the atmosphere outside the enclosure. This protection is also useful against dust or mechanical damage.

The response time depends on the individual gas to be measured. The larger the molecular weight and molecular size of the gas, the longer the response time will be. For other effects, see 4.8 and 4.9.

5.2.2 Limitations

A concentration of oxygen of 10 % (V/V) or more is required for correct operation of the sensor, see annex A.

This type of sensor is not recommended for the detection of gas/air mixtures above the lower explosive limit. Above the lower explosive limit, a catalytic sensor may erroneously indicate that the gas concentration is below the LEL.

To prevent false alarms, it is recommended that the alarm level should not be set below 5 % LEL for methane, 10 % LEL for propane and butane and 20 % LEL for gasoline vapours.

Table 1 — Overview of gas detection apparatus with different measuring principles

	Catalytic sensor	Thermal conductivity sensor	Infrared sensor	Semi-conductor sensor	Electro-chemical sensor	Flame ionization detector	Flame temperature analyser	Photo ionization detector	Para-magnetic oxygen detector
Details in subclause	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	5.10
O ₂ required in gas sample	yes	no	no	(no)	(no)	(no)	yes	no	not applicable
Typical measuring ranges combustible gases	≤ LEL	(0)–100 %	0–(100) %	≤ LEL	≤ LEL	≤ LEL	< LEL	< LEL	not applicable
Typical measuring ranges for oxygen	not applicable	not applicable	(0–100) %	not applicable	0–25 % (0–100 %)	not applicable	not applicable	not applicable	0–100 %
Combustible gases not measurable	large molecules	see 5.3	H ₂	(see 5.5)	alkanes	H ₂ ; CO	(see 5.8)	H ₂ ; CO; CH ₄ IP > X ⁵	combustible gases
Relative response time ¹	depends on substance	medium	(low)	depends on substance	medium	low	low	low	low to medium
Interference of non-combustible gases ²	no	CO ₂ ; Freons	(yes)	SO ₂ ; NO _x ; H ₂ O	SO ₂ ; NO _x	ClHCS ³ ; Halon	(Halon)	substance IP < X ⁵	NO; NO ₂
Poisoning ²	Si; (Hal ⁴); (H ₂ S); Pb	no	no	Si; Hal ⁴ ; SO ₂	(no)	(Si)	no	no	no
External gases required	no	no	no	no	no	yes	yes	no	(yes/no)
NOTE 1 Qualitative comparison between principles. The values do not take into account time for aspirated sampling lines.									
NOTE 2 Table gives common examples.									
NOTE 3 Chlorinated hydrocarbons.									
NOTE 4 Organic halogenated or inorganic halogen compounds.									
NOTE 5 IP is the ionization potential of the substance; X is the detector UV-lamp energy.									
(no),(yes) — For information on the statements in brackets, refer to the corresponding subclause.									

Changes of pressure, temperature and humidity have no significant effect within the specified range; however, the lower the alarm level is set the greater the significance will be of variations in temperature. The effect of air speed on diffusion systems is commonly reduced by the mechanical construction of the detector and by use of a permeable sintered metal element.

After exposure to concentrations of gas in excess of the measuring range, the sensor may need a recovery time of several hours or may have irreversible changes to its zero gas reading and sensitivity.

5.2.3 Interferences

The measuring principle is generally not selective because all combustible gases (in air) induce a signal. There is a wide variation in sensitivity to different gases which is not directly correlated to the LEL; however, it is possible to use the verified relative sensitivity (as supplied by the manufacturer) for the gas to calibrate the apparatus.

5.2.4 Poisoning

The catalyst may be poisoned after exposure to low concentrations of certain gases such that the sensor may eventually produce low, or zero response to the presence of combustible gas, for example by:

- silicones;
- tetraethyl lead;
- sulfur compounds;
- halogenated compounds (e.g. some halogenated hydrocarbons);
- organo-phosphorous compounds (e.g. in herbicides, insecticides).

The effect of poisoning depends on the poison itself, the gas to be measured and the temperature of the sensor. The manufacturer's guidance should be sought regarding which contaminants may poison the catalyst and how the sensor may be protected.

5.3 Thermal conductivity sensor

The following clauses give some typical information for this sensor type. This information is additional to the general information given in clauses 4 and 5.1.

5.3.1 Common applications

These sensors do not require oxygen for their operation and are capable of measuring concentrations up to 100 % (V/V) gas.

These sensors are suitable for detecting individual gases of high or low conductivity, relative to air, where air is the reference environment, see **A.2**.

The apparatus may be calibrated in any suitable range up to 100 % gas.

5.3.2 Limitations

Apparatus incorporating thermal conductivity sensors should not be used for measuring gas concentrations below the LEL except in the case of gases such as hydrogen for which such sensors are especially sensitive.

The reading of the apparatus may be in error if a flow sensitive type of thermal conductivity sensor is used when the gas flow is not stable.

5.3.3 Interferences

The thermal conductivities of combustible gases differ widely. Lighter gases (e.g. methane and hydrogen) are more conductive than air whereas heavier gases (e.g. non-methane hydrocarbons) are less conductive. The response to a gas mixture is therefore indeterminate unless the proportions of the constituent gases in the mixture are known. In the worst case, a mixture of high and low conductivity gases could produce no apparatus response. Influences of water vapour, temperature and pressure variations may be reduced by suitable construction methods; reference should be made to the instruction manual.

5.3.4 Poisoning

There are no known poisoning effects.

5.4 Infrared sensor

The following clauses give some typical information for this sensor type. This information is additional to the general information given in clauses 4 and 5.1.

5.4.1 Common applications

Infrared sensors may be used for the detection of most combustible gas(es) in any specified range of concentration up to 100 % (V/V) gas with the exception of hydrogen.

Oxygen has no influence on the signal when measuring combustible gases. These sensors do not require oxygen for their operation.

By appropriate selection of both wavelength and optical path length it is possible to have apparatus for:

- measuring the total amount of hydrocarbons;
- selective measurement of one single component (in a mixture);
- measurement down to ppm levels;
- measurement up to 100 % (V/V) combustible gas;
- measurement of up to 25 % (V/V) oxygen.

Measuring range and performance should be selected according to each application.

The principle of this type of apparatus allows the use of self-diagnostics to verify the response to the gas.

5.4.2 Limitations

These sensors will not detect hydrogen.

Dust and condensation may affect the response. Some types of sensor are susceptible to vibration. The time taken for the gas concentration in the optical path to reach the same value as the atmosphere to be measured will limit the response time of the apparatus. The response time may be short, particularly with aspirated apparatus. However, in practice, weather protection housings, gas filters and hydrophobic barriers, when fitted, may limit the response time attainable.

5.4.3 Interferences

Pressure variations do not affect the zero gas reading, but sensitivity is normally proportional to partial pressure. Since the sensor is sensitive to pressure, care should be taken to prevent alteration to the gas outlet pressure of the apparatus, see instruction manual.

Temperature effects are usually small but may increase or decrease the signal. Influences may be reduced by constructional precautions.

Other components (combustible or non-combustible) may induce a signal.

5.4.4 Poisoning

There are no known poisoning effects.

5.5 Semiconductor sensor

The following clauses give some typical information for this sensor type. This information is additional to the general information given in clauses 4 and 5.1.

5.5.1 Common applications

Semiconductor sensors may be used for the detection of gases over a wide range of concentrations; however, they have a non-linear response.

They are suitable for leak detection even at very low concentrations and for alarm only apparatus.

5.5.2 Limitations

New sensors may need a long "burn in time" (up to weeks) for stabilization of zero and sensitivity before calibration. This preconditioning should be carried out by the manufacturer.

Further preconditioning may be necessary after long periods (> 1 day) without power.

After exposure to concentrations of gas in excess of the measuring range, the sensor may need a recovery time of several hours or may have irreversible changes to its zero gas reading and sensitivity.

5.5.3 Interferences

The measuring principle is not selective, non-combustible gases may induce a negative or a positive signal.

There is a wide variation in sensitivity between sensors of the same type to particular gases and in addition, the relative sensitivity for these gases may vary significantly from one sensor to another. In general, there is a very wide variation in sensitivity to different gases which is not directly correlated to the LEL; refer to the instruction manual.

Variations of oxygen concentration, temperature, humidity or air speed may have a strong influence on the sensitivity; refer to the instruction manual.

5.5.4 Poisoning

The sensitivity may be strongly affected (mostly decreased, but in some cases increased) by poison concentrations higher than those which affect catalytic sensors. Examples of such poisons are:

- basic or acidic compounds;
- silicones;
- tetraethyl lead;
- sulfur compounds;
- cyanides;
- halogenated compounds.

The manufacturer's guidance should be sought regarding which poisons affect the sensitivity of the sensor and how the sensor may be protected.

5.6 Electrochemical sensor

The following clauses give some typical information for this sensor type. This information is additional to the general information given in clauses 4 and 5.1 .

5.6.1 Common applications

There are a limited number of applications of this type of sensor for explosion prevention. They are suitable for measuring concentrations of hydrogen or carbon monoxide up to the LEL, and oxygen up to 25 % (V/V). There are also sensors available for up to 100 % (V/V).

Additionally, this type of sensor is commonly used for measuring gas concentrations down to low ppm levels, for example, in leak detection and personal monitoring for toxic gases.

5.6.2 Limitations

Dependent on the type of sensor and the gas to be measured, the sensor may gradually be consumed by an overload of gas.

Electrolyte properties will limit the low temperature operation; see the instruction manual.

Response time and recovery time t_{90} are comparatively long, typically ≥ 30 s.

The lifetime of many types of oxygen sensor and some other sensors is dependent on the dose of gas to be measured because electrode or electrolyte will be consumed by the specific reaction.

Dependent on the sensor, oxygen is required for electrochemical reaction in the gas to be monitored or in the gas surrounding the sensor.

5.6.3 Interferences

Electrochemical cells may respond to other gases with a positive or negative change in signal.

With the exception of oxygen sensors, the sensitivity to interference may be in some cases higher than to the gas to be measured; refer to the instruction manual.

For some types of electrochemical sensors the change of sensitivity is proportional to pressure. Other types of sensor are affected or damaged by pressure pulses; refer to the instruction manual.

Low temperature or humidity may reduce the sensitivity and increase the response time of the sensor. However, some sensors have a reservoir containing material for maintaining humidity in order to avoid low humidity effects. In most cases the influence of temperature on the sensitivity of the sensor is well known and is reproducible. Therefore, the apparatus may have electronic temperature compensation.

There are specific interference effects for oxygen sensors arising from their use in non-air gas mixtures or in the presence of very high concentrations of combustible gases, such as:

- The molecular weight of the gas in which the oxygen is measured may have a strong influence on the sensitivity of the sensor. Therefore, calibration should be carried out using a defined concentration of oxygen in the same gas;
- The lifetime of the sensor may be reduced by high concentrations of organic solvents which react with the electrolyte.

5.6.4 Poisoning

The electrolyte or the electrode may be affected by other gases resulting in a loss of sensitivity; see the instruction manual.

The gas inlet of the sensor may be gradually reduced or even blocked by reaction products, for example, from hydrolysis of halogenated compounds like boron trifluoride (BF₃), silicone tetrachloride (SiCl₄) etc.

Some oxygen sensors may lose their sensitivity due to high concentrations of CO₂ in the atmosphere.

5.7 Flame ionization detector (FID)

The following clauses give some typical information for this sensor type. This information is additional to the general information given in clauses 4 and 5.1.

5.7.1 Common applications

This type of sensor is used where high sensitivity, wide measuring range, small measuring uncertainty, poison resistance and a fast response time are the main requirements. The sensor is suitable for measuring ranges from the ppm level up to the LEL and above.

This sensor is suitable for the measurement of gas at elevated temperatures

5.7.2 Limitations

The sensor is unsuitable for carbon monoxide and inorganic gases such as hydrogen.

The measuring principle is not selective.

External gases, hydrogen and synthetic air are required to provide fuel for the flame.

The sensor cannot be used with high concentrations of gases that will extinguish the flame, for example halon.

5.7.3 Interferences

The pressure of the gas sample, air and hydrogen, should be kept constant.

The flame arrestors used in the sampling line may be so soiled that it may be difficult to maintain a constant sample flow.

Halogenated hydrocarbons reduce the response when the apparatus is calibrated for measuring the total carbon content of the gas mixture, see **A.16**.

5.7.4 Poisoning

Generally there is no poisoning effect, but silicone compounds may result in a complete silica coating of the electrodes which will make the sensor inoperative.

5.8 Flame temperature analyser (FTA)

The following clauses give some typical information for this sensor type. This information is additional to the general information given in clauses **4** and **5.1**.

5.8.1 Common applications

This type of sensor is used to measure the total amount of combustible gases and vapours below the LEL when a fast response time is required.

This sensor is suitable for the measurement of gas at elevated temperatures.

5.8.2 Limitations

At higher concentrations the response is not linear. For range limitations refer to the instruction manual.

Not recommended for measurement in ppm range.

External gas(es) required. Hydrogen or another fuel is required for the flame.

Either oxygen is required in the gas to be measured or a separate air supply provided for the burner.

5.8.3 Interferences

The pressure of the gas sample, air and combustible gas, should be kept constant.

Higher halon concentration may decrease the signal by reduction of the flame temperature.

5.8.4 Poisoning

There is no known poisoning effect.

5.9 Photo ionization detector (PID)

The following clauses give some typical information for this sensor type. This information is additional to the general information given in clauses **4** and **5.1**.

5.9.1 Common applications

This type of sensor is used where high sensitivity, poison resistance and fast response time are the main requirements.

Usually the apparatus are of portable (hand-held) or transportable type and have an aspiration pump built in. The sensors are typically used in spot reading apparatus.

This sensor is suitable for the measurement of gas concentrations from low ppm range up to approximately 2 000 ppm.

Additionally, this type of sensor is commonly used for measuring gas concentrations down to low ppm levels for short periods of time, for example, in leak detection.

5.9.2 Limitations

The measuring principle is not selective for combustible gases. All substances which have an ionization potential (IP) lower than the energy of the UV-lamp of the device generate a signal. Substances with a higher IP than the lamp energy will not be detected (refer to the documentation of the apparatus).

The sensor is unsuitable for carbon monoxide, hydrogen, methane, low alkanes and all other compounds having ionization potentials higher than the lamp energy of the detector. Most sensors have a UV lamp with an energy of 10,6 eV. However, lamp energies may range from 8,4 eV to 11,7 eV for use in air.

This type of sensor is not recommended for measuring higher concentrations because the response is not linear. For range limitations refer to the instruction manual.

5.9.3 Interferences

The sensor will respond to all substances having an ionization potential (IP) lower than the energy of the UV lamp, typically 10,6 eV, but the response factor depends strongly on the ionization properties of the gas.

Humidity may induce a signal equivalent to several ppm. This signal is not related to ionization (IP of H₂O is 12,6 eV) but may be caused by an interaction with material surrounding the electrodes.

The relative sensitivities to different substances may be very different. Substances with an IP just below the energy of the UV lamp will induce a significantly lower signal than substances with a much lower IP.

A high concentration of methane in the presence of the substance to be detected may reduce the reading by inhibiting the ionization.

5.9.4 Poisoning

Generally there is no known poisoning effect.

The measurement of certain compounds like esters or styrene may lead to decomposition products being deposited on the UV lamp. Therefore, regular cleaning of the UV lamp is recommended (refer to instruction manual).

5.10 Paramagnetic oxygen detector

The following clauses give some typical information for this sensor type. This information is additional to the general information given in clauses **4** and **5.1**.

5.10.1 Common applications

This type of sensor is used for measurement of oxygen where selectivity, long term stability, and poison resistance are the main requirements.

This sensor is suitable for the measurement of oxygen concentrations in ranges between 0 % to 1 % (V/V) and 0 % to 25 % (V/V) oxygen. Measurement of up to 100 % (V/V) is possible. The difference between the lower and upper limits of the measuring range has to be greater than 0,5 % (V/V) oxygen.

Dependent on the particular detection method used, response times between 6 s and 40 s are typical.

5.10.2 Limitations

Dependent on the particular detection method used, the apparatus may:

- require external gas(es);
- contain ignition sources (heater);
- be sensitive to shock and/or vibration.

In most cases pressure and/or temperature correction is necessary.

5.10.3 Interferences

Except for NO and NO₂, which give signals of around 50 % and 4 % respectively of the oxygen signal, there are no significant interferences by other gases, see A.1.9.

5.10.4 Poisoning

There is no known poisoning effect.

6 Operation of fixed gas detection systems

6.1 General

For the reliable operation of a fixed gas detection system each sensor should be placed in a suitable location according to its individual application. Inspection and maintenance including recalibration with gas should be carried out periodically by trained personnel. If the user is not able to address these points the work should be carried out by the manufacturer or other competent person.

It is important that the instruction manual is read and followed.

Many factors need to be considered when specifying the monitoring site and determining the number of sensors required, including industry standards and/or regulatory authority requirements.

6.2 Installation

A fixed gas detection system should be installed such that it is capable of monitoring those parts of a plant or other premises where combustible gas(es) may accidentally accumulate. The system should be capable of giving an early warning of both the presence and the general location of an accidental accumulation of combustible gas(es), in order to initiate one or more of the following actions, either automatically or under manual control:

- increase ventilation;
- remove the hazard;
- shut down the plant process;
- safely evacuate the premises.

The length of any sampling line should be as short as is reasonably practicable. Adequate drainage and/or heating should be incorporated into the system design to minimize moisture and water condensation in the apparatus, detector head, and interconnecting cable/conduit system. Any combustible gas introduced

into the sampling systems should be vented in a safe manner. In general, a fixed system should be installed such that failure of individual elements of the system, or their temporary removal for maintenance, does not compromise the safety of the premises being protected. Duplication or triplication of remote sensors and control apparatus is recommended in all areas where continuous monitoring is required.

Breakdown or fault of the main power supply should be detectable since the safety of the monitored area has to be preserved. It is strongly recommended that for indication of power and/or apparatus failure, contacts are used which are closed in the non-activated state.

Appropriate precautions, for example the use of screened cables, should be incorporated when installing the complete cabling system (including that to ventilation controls etc.) to ensure that the total system is immune from the effects of electromagnetic interference.

Gas detection apparatus should be installed and used in such a way that only authorized personnel have access to the functional controls of the apparatus.

Sensors should be installed as late as possible in any programme of construction (i.e. the erection of new plant, refitting or maintenance) to prevent damage to the sensors resulting especially from welding and painting activities. However, installation should be completed on the site to be protected prior to the introduction of any combustible gas or vapour.

6.3 Criteria for the placement of sensors and sampling points

Sensors and sampling points should be placed such that gas accumulations are detected before they create a significant hazard. The placement of the sensors and sampling points should be determined following the advice of experts having specialist knowledge of gas dispersion, experts having a knowledge of the process plant system and equipment involved, and safety and engineering personnel. The agreement reached on the locations of sensors and sampling points should be recorded.

Fixed sensors and sampling points should be installed in locations such that they are not vulnerable to mechanical or water damage from normal operations in the area. Sensors should be readily accessible to permit regular calibration, maintenance and electrical safety inspection. If it is impossible to achieve regular direct access to the sensor then, as a minimum requirement, some form of automatic remote gas calibration facility should be provided.

Factors which should be taken into account when determining suitable locations include (not in order of priority):

- indoor or outdoor site;
- potential sources — the location and nature of the potential vapour/gas sources (e.g. pressure volume and/or mass, source temperature, density, and distances) need to be assessed, see annex B;

- c) chemical and physical data of the potential gases/vapours present;
- d) leak control may be difficult for low volatile liquids since they produce low vapour concentrations;
- e) nature and concentrations of possible gas releases (e.g. high pressure jet, slow leaks, spillage of liquids), see annex B;
- f) presence of cavities and jets;
- g) topography of the site;
- h) air movements, see annex B;
 - indoors: natural ventilation, mechanical ventilation; and
 - outdoors: wind speed and direction;
- i) temperature effects;
- j) local environment of the plant;
- k) location and number of personnel in the plant;
- l) location of potential sources of ignition;
- m) structural arrangements (such as walls, troughs, or partitions) which could allow gas to accumulate.

If there is significant ambient air movement or the gas is released into enclosed spaces, then the behaviour of gas is modified. The behaviour of gases following a release is complex and depends on many parameters. However, knowledge of the influence of these parameters is not sufficient, in practice, to predict the extent and/or build-up speed of a flammable atmosphere. The prediction may be improved by:

- 1) the application of generally accepted empirical rules developed by experts, based on their past experience;
- 2) on site experimentation to simulate and describe precisely the behaviour of the gases. This includes the use of smoke tube tests, anemometer readings or more detailed techniques such as tracer gas analysis;
- 3) numerical simulation of gas dispersion.

Excessive and low ambient temperatures may cause detection errors and reduce sensor life. In addition, at high and low temperatures the sensor may operate outside the temperature range specified by the manufacturer and may no longer comply with its certification. In general, the positioning of gas sensors directly above sources of heat such as ovens and boilers should be avoided and a suitable position at an adequate height away from the source of heat should be chosen. All sensors, sampling points and apparatus should be mounted in areas which will ensure compliance with the manufacturer's operating specifications.

Equipment should either be capable of being operated within the limits of vibration specified or should be provided with vibration isolation mountings.

Precautions should be taken to protect sensors and sampling points from the damage resulting from exposure to corrosive atmospheres (e.g. ammonia or acid mist).

Sensors and sampling points mounted in positions where they may be exposed to mechanical damage should be adequately protected in accordance with recommendations provided by the manufacturer.

Sensors and sampling points should not be exposed to contaminants which may adversely affect their operation. For example, materials containing silicones should not be used where catalytic sensors are installed.

The practice of washing of plant with water under pressure may cause severe degradation of gas sensors and should be avoided in areas where these are located.

6.4 Operation

After the initial gas calibration, fixed systems should automatically revert to the monitoring mode after a pre-determined interval without further adjustment. However, to ensure correct operation, it is essential to carry out both inspection and recalibration periodically. Routine tests of the combustible gas detection system is an extremely important factor affecting the reliability of the units. Optimum system performance and reliable operation will only be achieved through a defined program of comprehensive tests.

It is essential that safety is maintained by appropriate measures when the gas detection system, or a part of it, becomes inoperative during calibration, or if it is removed from service. Appropriate measures may be:

- use of a duplicate system;
- use of portable or transportable apparatus;
- increasing ventilation;
- eliminating ignition sources.

6.4.1 Initial operational control and gas calibration

The complete gas detection system including all ancillary equipment should be inspected prior to use to ensure that the design and installation has been carried out in a satisfactory manner. A check should be made to confirm that a full set of operating instructions, plans and records for the complete system have been supplied. The instructions should include details on use, testing, calibration and operation.

For maintenance and record purposes, plans of the installation should be provided that show the locations of all parts of the system (control units, sensors and sampling points, junction boxes, etc.) together with the routes and sizes of all cables. Junction box and distribution cable diagrams should also be included.

The records should be updated when any changes are made to the installation.

In the case of apparatus only indicating up to the LEL, the alarm set point (or the lowest set point, where there are two or more) should be as low as possible taking into consideration the need to avoid false alarms. Adjustments should be carried out in accordance with the manufacturer's instructions. After installation on site, each sensor should be calibrated according to the manufacturer's instructions.

Calibration should only be carried out by a suitably trained and competent person.

6.4.2 Inspection

The detection system should be frequently inspected by a competent person. The inspection should be in accordance with the instructions of the manufacturer and the specific requirements of the application. The intervals may be specified by the manufacturer or by regulations of the responsible authorities. If different intervals are defined the shortest time period should be taken.

A visual inspection of all units of the gas detection system should be carried out and the test functions should be checked. Special attention should be taken to look for contamination (e.g. dust or soil) and condensation of water or solvents in sampling systems and at the sensor locations.

The manufacturer's operational instructions should be followed with regard to:

- periodic cleaning of filters, sensor windows etc.;
- assembly of required materials, for example, auxiliary gas for some devices;
- safe operation of the system.

The results of all inspections should be recorded.

6.4.3 Maintenance and recalibration

Maintenance operations should not compromise safety in the area being protected. Defective apparatus should be removed for repair in a workshop outside the area being protected. If a replacement apparatus cannot be provided immediately, then transportable apparatus should be used as a temporary substitute.

Maintenance procedures should be undertaken only by suitably qualified personnel trained in the operation, maintenance, and repair of combustible gas detection apparatus. If the maintenance facility is not adequately equipped and/or qualified personnel are not available to perform the manufacturers recommended checkout and maintenance procedures, the user should return the apparatus to the manufacturer or other qualified repair outlet.

Complete and explicit instructions for testing and the checking of replaceable apparatus components should be obtained from the manufacturer. Suitable parts lists and schematics should be provided in the instruction manual. The manufacturer's instructions should be followed when deciding whether to replace an assembly or repair it by replacing a component part. If components are replaced, the replacement components should meet the specifications and tolerances of the original components.

The gas detection system should be checked and recalibrated periodically by competent persons, based on the service and maintenance instructions of the manufacturer. The intervals may be specified by the manufacturer or by regulations of the responsible local authorities.

Depending on the application, it may be necessary to choose more frequent calibration intervals. In all cases, the calibration interval should be such that all measuring deviations are within the instrument accuracy.

During the recalibration procedure, indication and accuracy should be checked by suitable methods and the values should be compared with the value of the initial calibration. The accuracy check should be carried out by using the appropriate calibration gas usually supplied from gas cylinders. If a certified calibration gas cylinder is not available, a reference gas approved by the manufacturer or another method with an appropriate accuracy may be used. Usually clean air is used as zero gas, and a calibration gas with a concentration slightly above the alarm levels is used for the sensitivity test, however, the instructions of the manufacturer should be followed. If this check leads to a result clearly different from the initial value of the manufacturer or from the previous check, appropriate remedial action should be taken, for example, shortening the calibration interval or replacement of the sensor or sensing element.

Depending on the specific application, the following should be checked:

- the suitability of the whole system;
- the checks required for specific types of sensor;
- the placement of sensors;
- the alarm levels and automatic output functions in case of alarm;
- the sampling system;
- the devices for data transmission and indication.

After any defective functions are corrected (repaired or replaced in strict accordance with the manufacturer's instructions), a full maintenance and calibration procedure should be conducted.

Defective units should be either:

- a) returned to the manufacturer; or
- b) returned to a repair agent authorized by the manufacturer; or
- c) repaired in a special workshop set up by the user for gas detector maintenance.

The results of maintenance and recalibration should be recorded.

7 Operation of portable and transportable gas detection apparatus

7.1 General

For safe and reliable operation of gas detection apparatus, inspection and maintenance including recalibration should be carried out periodically by a competent person. This work may be carried out by the user, the manufacturer of the apparatus or a sub contract service engineer.

It is also important that the instruction manual is read and followed.

Various types of portable and transportable gas detection apparatus may be used in a variety of ways according to their particular design and specification. Small, hand-held apparatus may be used for leak-seeking or spot checks. Larger portable apparatus, some with visual and/or audible alarms, may be used in multi-role mode including leak-seeking, spot checking, and local area monitoring functions, according to the particular needs of the user.

Transportable apparatus is intended for use for temporary area monitoring in locations where there is a probability of generating potentially combustible gas or vapour mixtures. Transportable apparatus is not intended to be hand carried for long periods of time, but is intended to be in place for periods in excess of hours.

Apparatus, where possible, should not be exposed to adverse climatic conditions, for example the back shelf of a car, and should be protected from mechanical damage.

Personnel required to use portable or transportable gas detection apparatus should have been properly trained in its use and have ready access to the operating instructions.

7.2 Operation

Most types of combustible gas detection apparatus are not sensitive to a specific gas. The presence of gases other than that for which the apparatus is calibrated may adversely influence its response. Where an apparatus is to be used to detect the presence of more than one gas it should be calibrated accordingly. The calibration may be with several different gases or with the gas to which the apparatus is least sensitive.

However, gas detection apparatus of this kind should not be regarded as being suitable for a gas analysis. Where unknown substances are likely to be encountered, low alarm or action set points should be chosen to allow for variations in sensitivity.

In areas being surveyed with portable apparatus where gases or vapours may be stratified rather than uniformly mixed, spot checks should be made at different levels.

When sampling vapour above a liquid, care should be taken to avoid the sampling line or sensor from coming into contact with the liquid, since this may block the gas entry to the apparatus. Only sampling lines with a liquid separation unit or micro filter should be used.

When subjecting a portable apparatus to a temperature change, it is important that time is taken to allow the apparatus to reach the new temperature to avoid vapour condensation which may cause incorrect readings.

Saturated steam may physically block the flame arrestors of certain types of gas sensor, so as to make them inoperative, and care should be exercised accordingly.

Care should be taken to ensure that the materials from which the apparatus has been constructed are compatible with the gas or vapour to be detected. For example, pure copper or copper alloys with high copper content contained in any apparatus likely to be used for the detection of acetylene or its derivatives lead to the possibility of the formation of potentially explosive or percussive acetylides when coming into contact with the gas to be monitored.

Routine testing of the combustible gas detection apparatus is an important factor affecting reliability. Optimum system performance and reliable operation will only be achieved through a program of tests.

7.2.1 Inspection and field-check

Inspection should be performed in accordance with the manufacturer's instruction manual and immediately prior to use. A sequence of inspections may include the following.

- a) Resetting of the mechanical zero of analogue meters.
- b) Checking the tightness of all electrical connections (remote detector head, power supply etc.).
- c) Allowing adequate warm-up time.
- d) Checking for sample-line leaks and proper flow.
- e) Checking for clogged or dirty flame-arresting systems.
- f) Checking the battery voltage and/or battery condition and making any required adjustments or battery replacements.
- g) Performing a test of the failure (malfunction) circuit(s).
- h) Checking that a zero reading is displayed when operated in clean air and the response test, as follows.

Place the detector head (integral or remote) or the sampling line in an atmosphere free of combustible gas, aspirate a large enough sample to purge the lines (applicable only to apparatus with sampling lines). If a significant deviation from zero is observed, the apparatus should be recalibrated.

The response (sensitivity) of the apparatus should be checked using the field calibration kit in accordance with the manufacturer's recommendation and a known combustible gas/air mixture equivalent to 25 % to 75 % of the full-scale concentration for which the apparatus is indicated to be used. If the test results are not within ± 10 % of the applied gas concentration, the apparatus should be recalibrated.

For alarm-only apparatus, a test gas concentration should be applied which is equal to 5 % LEL above the highest alarm set point of the apparatus. All alarms should actuate during this test. If an apparatus fails this procedure, and suggested corrective action does not solve the problem, the apparatus should be recalibrated.

The results of these checks should be recorded.

7.2.2 Maintenance and recalibration

Maintenance procedures should be undertaken only by qualified personnel trained in the operation, maintenance, and repair of combustible gas detection apparatus. If the maintenance facility is not adequately equipped and/or qualified personnel are not available to perform the manufacturer's recommended checkout and maintenance procedures, the user should return the apparatus to the manufacturer or other qualified outlet of repair. In the case of Ex or EEx certified apparatus, the manufacturer should be consulted with regard to replacement parts.

For portable and transportable gas detection apparatus, it is important that the whole unit should be removed to a non-hazardous location for inspection and maintenance.

After any defective functions are corrected (repaired or replaced in strict accordance with the manufacturer's instructions), a full maintenance and recalibration procedure should be conducted.

Defective units should be either:

- a) returned to the manufacturer; or
- b) returned to a repair agent authorized by the manufacturer; or
- c) repaired in a special workshop set up by the user for gas detector maintenance.

The results of maintenance and recalibration should be recorded.

8 Training

Training should be provided for those maintaining and using. A distinction is made between "Operator" and "Maintenance" training only for the sake of clarity and the fact that normally those using the system will not be responsible for its maintenance. It is important to establish these roles at an early stage.

8.1 Operator training

Operator training should be designed to ensure operator understanding and familiarity with the system. Additionally, it should advise and show operators how to make visual and functional checks, and whom to contact if the unit(s) are believed to be malfunctioning. It is particularly important that operators should have instructions to be followed in the event of a gas detector alarm. An annual refresher training session should be given.

Instructions should be drafted prior to the installation of the detection system and should include such items as what to do in the event of an alarm, the safety considerations for each unit, and whom to contact if a detector head or system malfunction is discovered.

8.2 Maintenance training

Maintenance training should be designed for those charged with system maintenance and system calibration. It should include details of how to perform calibration, how the detector functions, etc.

Training may be done in-house by knowledgeable persons, or by vendor assisted training sessions.

Vendor literature should be obtained and made available to these persons.

Annex A (informative)

Physical and chemical principles of sensors

A.1 Catalytic sensors (see 5.2)

The principle of operation of the catalytic sensor depends upon the oxidation of combustible gas at the surface of an electrically heated catalytic element. This oxidation causes a measurable temperature increase of the sensing element dependent on the concentration of gas detected.

The sensors are normally constructed as an electrical half-bridge with two electrically similar filaments or beads mounted close to one another. Usually both filaments are embedded in ceramic, one (the sensing element) is additionally covered with the catalyst(s). Both elements are electrically heated to a temperature between 450 °C and 550 °C. The oxidation causes the temperature of the sensing element to rise relative to the reference element. The difference in temperature results in a difference in the electrical resistance of the filaments causing the (Wheatstone) bridge to become unbalanced. This produces an out-of-balance signal used as a measurement signal. An oxygen concentration of approximately greater than 10 % (V/V) is required for a catalytic sensor to operate, since oxidation depends on the presence of oxygen. Gas/air concentrations up to the lower explosive limit are measurable with acceptable linearity. As the catalytic sensor consumes combustible gas and oxygen, a continuous diffusion of gas to the sensing element is required.

Catalytic sensors are susceptible to permanent or temporary inhibition of the catalyst by certain contaminants such that the sensor may eventually produce low, or zero response to the presence of gas. Permanent inhibition, usually known as “catalyst poisoning”, may result from exposure to substances such as silicones, tetraethyl lead, sulfur compounds and organo-phosphorus compounds. In some cases temporary inhibition may be caused by, for example, some halogenated hydrocarbons. So called “poison resistant” sensors tolerate much higher doses of those contaminants before they suffer inhibition. Sensors may be protected, in some cases, by the use of activated carbon or other types of filter. However, carbon filters should be used with great care; while they may offer excellent protection from contaminants, they may also prevent the detection of higher hydrocarbons and may result in considerably extended response times. Filters have a limited lifetime and require replacement.

The performance may also be affected by the level of humidity in the atmosphere, changes in temperature and air velocity. Due to compensation, changes of pressure, temperature and humidity have no significant effect within the specified range.

A.2 Thermal conductivity sensors (see 5.3)

These sensors are suitable for monitoring those gases whose thermal conductivity differs greatly from that of the reference environment (usually air).

The sample gas is passed over an electrically heated filament or bead at a constant gas-flow. The temperature of the filament, which determines its electrical resistance, is determined by the loss of heat through the surrounding gas and is dependent on the molecular mass and other physical properties of the molecule. Usually, there is a compensation element in a reference gas to eliminate the influence of external temperature fluctuations. Indication relative to clean air is positive with high sensitivity for gases such as hydrogen, helium, neon in air and acceptable sensitivity for methane in air. Indication relative to clean air is negative for gases heavier than air or having special molecular properties.

The response to a gas mixture is indeterminate unless the proportions of the constituent gases in the mixture are known. In the worst case, a mixture of high and low thermal conductivity gases could produce no apparatus response. The sensor is capable of measuring high concentration even in the absence of oxygen and is independent of the oxygen level in the gas-flow.

A.3 Infrared absorption sensors (see 5.4)

Optical sensors detect the attenuation of light by molecules in an optical path.

Light from a source passes along an optical path and, after filtering, reaches an optical detector. The light source may be a (tungsten) bulb lamp or a light emitting diode (LED) usually emitting in the near infrared region. The optical path may have a length of some centimetres or more and probably may use multiple reflection. It can be open (or nearly open, shielded by a diffusion barrier) or a sealed cuvette with gas inlet and outlet; there may also be a reference path. Light filtering is performed either by periodically bringing filters into the optical path or using static filters sharing parts of the path. Frequently, the light beam is chopped to operate the detector with a modulated signal. The reference wavelength(s) are located in regions, where unattenuated transmission is expected. Detectors may be photo-diodes, photo-multipliers, photo-resistors, vacuum photocells, semiconductor cells, optoacoustical detectors, opto-thermal-capacitative systems (usually with negative filtering), pyroelectric detectors, etc. Fibre optics may be inserted at the ends of the optical path to prevent the sensitive optical parts from damage or corrosion and to facilitate protection against ignition by optical or electrical components of the apparatus.

The FTIR-technique (Fourier Transform Infra-Red), used in analytical and some environmental applications, is not yet of practical importance for the detection and measurement of combustible gases for industrial safety applications and is not described here.

Due to the wide range of construction methods, which can partly be combined, it is virtually impossible to summarize the optical properties for the detection of combustible gases.

Sensitivity, response factors and selectivity for special gases should be considered when selecting apparatus. Some common features are:

- Hydrogen cannot be detected, because it does not attenuate light in the infrared wavelength region.
- The measuring wavelength for hydrocarbons is often located in the range of C-H vibrational transition (about 3,3 μm).
- For the detection of combustible gases in air in the range of 0,1 % up to 100 % (V/V) interference gases of major influence are not to be expected, except for water vapour, which has interfering absorption in the infrared.
- Optical apparatus do not suffer from poisoning effects.
- Air velocity does not affect the sensor.
- The response time is mainly limited by the time taken for the gas to be introduced and flush out the optical cell.
- In practice, weather protection housings and filtration/hydrophobic filters will impose limits on the response time.
- The optical system may be affected by dust or condensation (deposited on mirrors) or may be sensitive to vibrations (e.g. photoacoustic detectors).
- Reduced maintenance through self diagnostics, automatic calibration, checking capabilities and compensation for dirt accumulation on the optics may extend operation periods between service.
- Failure of the source or excessive contamination of the optical system can be detected and indicated as a warning.

A.4 Semiconductor sensors (see 5.5)

This type of sensor is based on electronic conductivity effects associated with chemisorption of gases on a semiconductor surface.

Semiconducting material (metal oxide often based on tin oxide) is electrically heated up to a few hundred degrees Celsius. Electrodes are implanted or otherwise mounted on the surface. Resistance changes can be measured when the semiconducting element is exposed to gases other than air. Sensors are used for the detection of gases in any concentration; however, they tend to have a non-linear response. Sensitivity decreases with increasing concentration. In many cases, semiconductor sensors require oxygen to operate, and humidity or oxygen changes may effect their response.

Some semiconductors also respond to substances other than flammable gases and vapours; they are in general non-specific and susceptible to interference. There are large differences in response factors for combustible gases. Hydrogen is detected at high sensitivity, whereas some gases (e.g. NO_2) may produce negative signals, so the influence of interference gases has to be investigated for every individual application.

Response times depend on the manufacturing properties of the sensing element, the concentration of the gas to be measured and the gas transport system to the sensor (mostly by diffusion).

A.5 Electrochemical sensor (see 5.6)

Operation of an electrochemical sensor depends upon changes of the electrical parameters of electrodes (in contact with an electrolyte) due to redox reactions of the gas on the surface of the electrodes.

The electrodes may be covered with an activating layer, which is responsible for the reaction. Some electrochemical sensors use an additional pre-reaction, the products of which result in electrochemical reaction at the contact surface of electrode and electrolyte. Usually the gas is consumed by the redox reaction; waste products are commonly transported through the cell to the counter electrode. The electrodes and electrolyte are usually confined by semi permeable membranes which allow the gas to permeate to the electrode-electrolyte interface. Since only small quantities of gas can be consumed at the electrode, diffusion may additionally be limited by aperture or capillary means to prevent the system from overloading.

Low detection limits down to ppm concentrations are possible. Electrochemical sensors are also suitable for measuring concentrations of hydrogen or carbon monoxide in the (0 to 100) % LEL range. However, they are not available for detecting alkanes. Since the electrochemical sensor may gradually be modified or consumed by reactive gases, it therefore requires replacement at suitable intervals.

Electrochemical cells may detect other interfering gases. Periodic adjustment is necessary to correct for drifts in zero and sensitivity. Response time and recovery time t_{90} are comparatively long (typically > 30 s), especially after overload. Low temperature operation (< -15°C) may be precluded by electrolyte properties. Lack of humidity may dry out the cells and make them inactive.

A.6 Flame ionization detectors (FID) (see 5.7)

This detection principle utilizes electrical (ionization) changes in a hydrogen flame.

Ionized atoms or molecules generated in the flame are transported by an electric field and thus measured as an electric current. The electric field is generated by applying a (positive) voltage of up to a few hundred volts to an electrode near the flame (with the gas jet as the counter electrode).

This type of detector has excellent linearity over a range up to several decades. A flame of pure hydrogen (and air) produces a negligible number of detectable ions giving a base current of less than 0,1 picoamperes, which allows the measurement of mass flows down to 10–15 pg/s. The response time of an FID is mainly determined by time to feed the sample gas to the flame; response times below one second can be obtained.

FIDs are usually constructed with a miniaturized burner in a small cylinder with the collecting electrode(s) within the cylinder. The hydrogen should not contain organic compounds and other pollutants, but can contain some amount of gases such as nitrogen, oxygen, water vapour, etc. Part of the sample gas flow is mixed into the hydrogen flow to the gas jet. Combustion air which should be kept free of contaminants is normally fed through a ring slit into the combustion chamber. All gas flows should be held constant at optimized levels and the temperature of the combustion chamber should be stabilized.

The ionization process in the flame depends on the type of atoms and their oxidation state. As an empirical rule, C-H bonds, unsaturated C-C bonds and C-halogen bonds are ionized and measurable. C-O bonds in molecules do not produce detectable ions. Excess oxygen in molecules compensate the ionizing effect, and thus are subtracted from the count of carbon bonds to calculate the response factor if the FID is used as total carbon analyser. Inert and rare gases, nitrogen oxides, halogens, hydrogen, nitrogen, oxygen, carbon monoxide, carbon dioxide, carbon disulfide, carbon tetrachloride, formic acid, hydrogen cyanide, ammonia, water, hydrogen sulfide and comparable gases give no response. There are major deviations from the empirical rule for response factors in the range of 1:3 to > 3:1, compared to methane. Response factors also depend on the construction of the combustion cell, gas flow and electrical parameters and the choice of carrier gas.

Care should be taken if silicon-containing molecules are present in the sample gas, because an isolating layer of silica may coat the electrode, which may inhibit the ion transport and thus reduce the detector signal.

A.7 Flame temperature analyser (FTA) (see 5.8)

This detection principle is based on the change of temperature of a flame in presence of combustible gases or vapours.

Inside a small detector chamber the temperature of a continuously burning flame is measured by a detector. When combustible gases or vapours are drawn from a sample point into the chamber and incinerated by the flame, the temperature detector measures the resulting change in flame temperature. The resulting signal is non-linear in relation to the gas concentration detected.

The response time of an FTA is mainly determined by time to feed the sample gas to the flame; response times below five seconds can be obtained.

The burner gas (usually hydrogen) for the reference flame should not contain organic compounds and other contaminants. To ensure a stable zero signal, in the absence of the gas to be measured, all gas flows should be held constant at optimized levels in order to maintain a stable temperature of the combustion chamber.

Care should be taken in the presence of halon in the gas to be measured. Gas samples containing halon but not containing combustible gas will reduce the flame temperature; this should be detectable by the apparatus. Halon at high concentrations in the presence of combustible substances may cause a misreading.

A.8 Photo ionization detector (PID) (see 5.9)

The detection principle is based on ionization of gaseous compounds by ultraviolet (UV) radiation. The gas is radiated by a UV source with an emission energy of, for example 10,6 eV. Molecules are then photo-ionized and the resulting ion current is measured across an applied electric field. Molecules having an ionization potential (IP) equal or lower than the excitation energy of the UV lamp are detected. In principle, as the measurements are performed in air, all substances having an IP higher than oxygen (IP = 12,1 eV) cannot be detected.

Ionization potential of various substances can be found in the literature or a list may be obtained from the instrument supplier. Examples of compounds which can usually be detected include: organic molecules containing several carbon atoms and/or heteroatoms such as oxygen, sulfur, bromine; non-saturated and aromatic hydrocarbons; amines; several inorganic combustible compounds such as ammonia, hydrogen sulfide and carbon disulfide; and some non-combustible gases such as nitrogen dioxide, nitric oxide and trichloroethylene.

Molecules such as hydrogen, carbon monoxide and methane have IP's higher than oxygen. Substances like ethane, propane, acetylene or methanol have IP's higher than 10,6 eV. Other substances such as ethanol and ethylene with an IP of 10,5 eV which is very close to the commonly used lamp energy of 10,6 eV and give a low response.

The main components of a PID are the UV lamp with lamp driver (high voltage or high frequency method), two collector electrodes with amplifier, and typically a sample filter and pump. No consumable gases are required.

The response time is determined by the sample gas flow only. Typical response times are between 2 s and 10 s.

A.9 Paramagnetic oxygen detector (see 5.10)

The technique employs the magnetic properties of gaseous compounds for their detection and measurement. The mass (magnetic) susceptibility of most substances is very low (they are solely diamagnetic, resulting in a weak, negative interaction with a magnetic field). However, some substances are also paramagnetic which results in a stronger positive interaction. Oxygen has a mass susceptibility two orders of magnitude greater than most other gases, except for nitric oxide (mass susceptibility of approximately 50 % of oxygen) and nitrogen dioxide (mass susceptibility of approximately 4 % of oxygen).

There are various techniques used to measure oxygen. Apparatus of the dumb-bell type utilizes a very light, small diamagnetic dumb-bell with a torsion suspension mounted in a strong non-uniform magnetic field. Torsion of the dumb-bell, caused by the interaction of paramagnetic gas with the magnetic field, is detected optically and a feedback loop electromechanically returns the dumb-bell back to balance. The signal is proportional to the mass susceptibility and thus the concentration of paramagnetic gas. The signal requires compensation for pressure and temperature. The instrument is also sensitive to shock and vibration.

Apparatus of the thermo-magnetic type uses the temperature dependence of the paramagnetic susceptibility which is approximately inversely proportional to temperature. The gas flow is divided into two paths. Gas in one stream is heated to approximately 100 K above ambient. A flow ("magnetic wind") is induced in the non-uniform magnetic field because of the difference in susceptibility of the paramagnetic gas at the two temperatures. This flow is detected by its cooling effect on a heater mounted in a bridge circuit. The out-of-balance signal from the bridge is used to measure the concentration. The instrument reading may be orientation dependent, therefore the apparatus should be fixed.

Apparatus based on the differential pressure (Quinke) effect transduce the pressure difference induced by flow of a paramagnetic gas attracted by a non-uniform magnetic field. A reference gas such as nitrogen with a very low flow rate is required. Pressure measurements, where the signal is proportional to gas concentration, are usually performed by modulating the magnetic field.

Annex B (informative)

Nature of a release

B.1 General

Sensors should be located in positions determined in consultation with experts having a specialist knowledge of gas dispersion, and those who have a knowledge of the process plant system and equipment involved, together with safety and engineering personnel.

Sensors located in buildings or enclosures are generally not exposed to adverse weather conditions. However, sensors located on outdoor sites and open structures may be subjected to severe environmental conditions, and account should be taken of these conditions at all times. For example, strong winds may cause drift of the zero reading, and even apparent transient loss of sensitivity during calibration, due to dilution of the calibration gas. Therefore, great care should be taken of the location of sensors in exposed sites, and adequate weather protection measures should be provided for the sensor. Steam, driving rain, snow, ice and dust, etc. may also adversely affect sensors.

B.2 Parameters influencing the release

B.2.1 General

The extent and/or build-up speed of a combustible atmosphere is mainly affected by the following chemical and physical parameters of the release, some of which are intrinsic properties of the combustible material, others are specific to the process. For simplicity, the effect of each parameter listed below assumes that the other parameters remain unchanged.

B.2.2 Release rate of gas or vapour

The greater the release rate the larger the extent and/or build-up speed of the combustible atmosphere. The release rate depends on other parameters, namely:

a) *Geometry of the source of release*

This is related to the physical characteristics of the source of release e.g. an open surface, leaking flange, etc.

b) *Release velocity*

For a given source of release, the release rate increases with the release velocity. In the case of a product contained within process equipment, the release velocity is related to the process pressure and the geometry of the source of release. A significant release rate combined with a high velocity will generate a momentum jet which will affect behaviour of the released gas at least in the vicinity of the source.

Gas escaping with high velocity (for instance, a leak from a pressurized line or container) will behave initially as a momentum jet directed away from the source of release. As the distance from the source of release increases, the momentum of the jet will decay until eventually the dispersion of the gas will be controlled by air flow and buoyancy effects.

c) *Concentration*

The concentration of combustible vapour or gas in the released mixture influences the release rate.

d) *Volatility of a flammable liquid*

This is related principally to the vapour pressure, and the heat of vaporization. If the vapour pressure is not known, the boiling-point and flash-point can be used as a guide. An explosive atmosphere cannot exist if the flash-point is significantly above the relevant maximum temperature of the combustible liquid. The lower the flash-point, the greater will be the extent and/or build-up speed of a combustible atmosphere. Some liquids (e.g. certain halogenated hydrocarbons) do not possess a flash-point although they are capable of producing an explosive gas atmosphere. In these cases, the equilibrium liquid temperature which corresponds to the saturated concentration at the LEL should be compared with the relevant maximum liquid temperature. Liquids have to be taken into account when their maximum temperature is above $(TF-x)$ K, where TF is the flash-point and x the safety margin. The safety margin is about 5 K in the case of pure chemicals and up to 15 K for mixtures in special cases.

NOTE Under certain conditions, the mist of a combustible liquid may be released at a temperature below its flash-point and still produce an explosive atmosphere.

e) *Liquid temperature*

The vapour pressure increases with temperature, thus increasing the release rate due to evaporation. The temperature of a liquid after it has been released may be increased, for example, by a hot surface or by a high ambient temperature.

B.2.3 Ventilation

An increased efficiency of ventilation usually reduces the extent and/or build-up speed of a combustible atmosphere. Obstacles which impede the ventilation may increase the extent and/or build-up speed of a combustible atmosphere. On the other hand, some obstacles, for example, bund, walls or ceilings, may limit the extent and/or build-up speed of a flammable atmosphere. For details refer to EN 60079-10. In case of very high gas concentrations (above LEL) or above a flammable liquid an increased ventilation may lead to an increased volume of the explosive atmosphere.

B.2.4 Relative density of the gas or vapour which is released

The behaviour of gas released with negligible initial velocity (for instance, vapour produced from a liquid spillage) is governed by buoyancy and depends on the relative density of the gas with respect to air.

If gas or vapour is significantly lighter than air, it tends to move upwards. If significantly heavier, it tends to accumulate at ground level. The horizontal extent and/or build-up speed of combustible atmosphere at ground level increases with increasing relative density and the vertical extent and/or build-up speed of a combustible atmosphere above the source increases with decreasing relative density.

NOTE For practical applications, a gas or vapour mixture which has a relative density below 0,8 is regarded as being lighter than air, for example CH₄, H₂, NH₃. If the relative density is above 1,2 it is regarded as being heavier than air. Between these values, both of these possibilities should be considered.

Sensors should be located in all areas where hazardous accumulations of gas may occur. Such areas may not necessarily be close to a potential source of release, but might for instance, be areas with restricted air movement. Heavier than air gases are particularly likely to flow like a liquid and to accumulate in cellars, pits and trenches if these are present. Similarly, lighter than air gases may accumulate in overhead cavities.

B.2.5 Source temperature and/or pressure

A temperature and/or pressure of the gas or vapour prior to the release significantly different from the ambient pressure and temperature may affect the absolute density of the release and hence its behaviour, at least in the vicinity of the source.

Note that a gas at high pressure escaping into the atmosphere may be strongly cooled as it expands adiabatically.

B.2.6 Other parameters to be considered

Other parameters such as climatic conditions and topography may also have to be taken into consideration.

If there is significant ambient air movement or the release is into enclosed spaces then the above behaviour is modified as described in the following sections.

B.3 Outdoor sites and open structures

In the case of outdoor sites and open structures the dispersion of gas following a release may be affected both by the wind speed and by the wind direction. In open areas, the lateral spread of gas upwind of the release is reduced, whilst downwind of the release it is increased. This effect is greater at high wind speeds. More complex air flow patterns occur around buildings or other structures. In these cases the wind direction may be a significant influence, and the possibility of gas accumulating in partially enclosed spaces, or in spaces with restricted air movement, should be considered. Where it is intended to install gas detectors in major plant, the use of mathematical models of gas dispersion, or of scaled wind tunnel tests, may be appropriate at the design stage.

Local thermal effects may be significant in controlling air flow patterns and may, therefore, influence the dispersion of gas. For example, large thermal gradients may be generated close to hot surfaces. In addition, the relative density of the gas will be affected by both the temperature of the gas itself and of the surrounding air.

Sensors should also be located close to any potential sources of major release of gas, although to avoid nuisance alarms, sensors should generally not be located immediately adjacent to equipment which may produce inconsequential leakage in normal operation. In general, on open sites minor leaks may be dispersed without causing a hazardous accumulation.

Where it is necessary only to detect the escape of gas from within a given area, then sensors may be placed at intervals around the perimeter of the site. However, such an arrangement may not provide an early warning of a release. This arrangement should not be used alone if a release could cause a significant hazard to personnel or property within the perimeter itself.

B.4 Buildings and enclosures

B.4.1 General

Within buildings and enclosures the tendency for gases to form a hazardous accumulation following a release is generally greater than in outdoor locations. When a gas is released into an enclosed space it mixes with the air in the enclosure to form a gas/air mixture. The manner in which this mixture forms will depend upon the gas release velocity, the location of the release, the gas density, ventilation, and any superimposed thermal flows. These factors should be taken into consideration in determining appropriate positions for sensors.

B.4.2 Unventilated buildings and enclosures

Theoretically in the absence of any ventilation air flow and/or thermal effects, the release of a lighter than air gas will tend to form a layer of gas/air mixture extending from the level of the source of release to the ceiling. The release of a heavier than air gas will tend to produce a layer of gas/air mixture extending from the level of the source of release to the floor.

If the release takes the form of a momentum jet this behaviour may be modified. For example, if a jet of lighter than air gas is directed downwards from the source of release, then the layer of gas/air mixture may extend from the ceiling to a position below the level of the source of release. Similarly, if a jet of heavier than air gas is directed upwards from the source of release, then the layer may extend from the floor to a position above the level of the source of release.

NOTE If a source of gas release is present in buildings or enclosures then there should be adequate ventilation provided.

B.4.3 Ventilated buildings and enclosures

The ventilation of buildings and enclosures is achieved by “natural means”, “mechanical means”, or a combination of the two.

NOTE When a release concentration has decreased to concentrations considerably less than the LEL it will tend to move with the normal air flow due to a small difference in density between gas and air.

B.4.3.1 Natural ventilation

Natural ventilation is the flow of air into and out of a building or enclosure through any purpose built or adventitious openings in its structure. Ventilation air flows are caused by two effects; firstly, any pressure difference across the enclosure created by wind and, secondly, buoyancy due to any difference in temperature (and hence density) of the atmosphere contained within the enclosure and the outside air. For natural ventilation due to the latter effect where the temperature in the building or enclosure is higher than that of the outside air, an upward flow will tend to be produced. Conversely, where the temperature within the building or enclosures is below that of the outside air a downward flow will tend to be produced.

The release of a gas or vapour into a naturally ventilated building or enclosure will tend to result in the formation of a gas/air mixture in a manner similar to that described in B.4.2. However, in this case the gas concentration in the mixture will be lower for a given release rate due to dilution by the ventilation air flow.

If a heavier than air gas or vapour is released into an enclosure in which natural ventilation produces an upward flow then the gas/air mixture may extend above, as well as below the level of the source of release. Conversely, if a lighter than air gas or vapour is released into an enclosure in which ventilation produces a downward flow then the gas/air mixture may extend below as well as above the level of the source of release.

NOTE Further information on natural ventilation is given in EN 50145.

B.4.3.2 Mechanical ventilation

Mechanical ventilation is the term used to describe air flow through an enclosure induced by mechanical means i.e. fans. Ventilation air flows set up by mechanical means can be high (e.g. greater than 12 volume changes per hour).

The gas concentration within an enclosure ventilated by mechanical means will, in general be much less than that resulting from a similar release into a naturally ventilated enclosure.

In a well designed system the whole volume within an enclosure is swept by the ventilation air flow. Where the geometry of the enclosure gives rise to regions of poor air movement or “dead spaces” a gas/air mixture may accumulate. Therefore, detectors should be sited in these spaces.

NOTE Smoke tracers may assist in identifying the air movement within an enclosure and the presence of any dead spaces where gas/air mixture may accumulate.

If a sensor is installed in the intake or exhaust duct of a mechanical ventilation system (depending where the release might occur), then the alarm set point should be set as low as reasonably practical.

B.4.4 Other factors

In general, sensors should be sited above the level of ventilation openings and close to the ceiling for the detection of lighter than air gases and below the ventilation openings and close to the floor for the detection of heavier than air gases.

Where it is required to detect the possible ingress of gas or vapour into a building or enclosure from an external source, sensors should be sited adjacent to the ventilation openings. These sensors should be in addition to any required for the detection of releases within the building or enclosure.

If ceilings or floors are compartmented by equipment or other obstructions, sensors should be installed in each compartment.

Any thermally induced flow (e.g. from hot surfaces or plant or equipment) may affect the distribution of a gas/air mixture.

Annex C (informative)

Measuring ranges up to LEL

C.1 Reference to the annex of EN 50054

Annex A of EN 50054 gives a list of flammability limits (i.e. LEL and UEL) of some combustible gases and vapours. Such data are available from a number of sources and there is no generally accepted and internationally agreed set of data to which reference can be made in standards on an authoritative basis. The concentrations noted in the annex of EN 50054 are the internationally agreed basis for the type testing of devices. National regulations may use differing values for the LEL of some substances and therefore different measuring ranges. To define a suitable measuring range for a specific application should be carried out in co-operation between user, local authorities and the manufacturer.

The latest values may be found in IEC 60079-20.

Annex D (informative)

Environmental parameters

D.1 Typical environmental conditions used in type testing

The following table lists values for the range of environmental parameters which are common for type testing. The values are based on the environmental tests of the European Standards EN 50054, EN 50057, EN 50058 and EN 50104. For further details and exact figures refer to these standards.

In any case the environmental conditions of the area(s) of use should be compared with the data specified by the manufacturer (instruction manual). In the case of larger variations of environmental conditions at the area(s) of use the manufacturer should be consulted.

Parameter	Based on EN 50054, EN 50057, EN 50058, EN 50104	
Unpowered storage	24 hour at each temperature sequentially -25 °C +20 °C (ambient) +55 °C +20 °C (ambient)	
Temperature	Integral sensor	-10 °C to +40 °C
	Remote sensor	-25 °C to +55 °C
	Separate control unit	+5 °C to +55 °C
Pressure	95 kPa to 110 kPa (EN 50057, EN 50058) 80 kPa to 120 kPa (EN 50104)	
Humidity	5 % r.h. to 90 % r.h.	
Air speed	up to 6 m/s	
Vibration (fixed and transportable apparatus)	Frequency range 10 Hz to 55 Hz Vibration amplitude 0,15 mm Sweep cycles per axis 10	
Drop test (portable apparatus and remote sensors)	mass < 1 kg	fall height 0,25 m
	mass 1 kg to 10 kg	fall height 0,10 m
	mass > 10 kg	fall height 0,05 m

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