BS EN 60079-29-2:2015

BSI Standards Publication

Explosive atmospheres

Part 29-2: Gas detectors — Selection, installation, use and maintenance of detectors for flammable gases and oxygen

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National foreword

This British Standard is the UK implementation of EN 60079-29-2:2015. It is identical to IEC 60079-29-2:2015. It supersedes BS EN 60079-29-2:2007 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EXL/31, Equipment for explosive atmospheres.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Published by BSI Standards Limited 2015

ISBN 978 0 580 79818 4
ICS 13.320; 29.260.20

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2015.

Amendments/corrigenda issued since publication

Date	Text affected

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 60079-29-2

May 2015

ICS 29.260.20

Supersedes EN 60079-29-2:2007

English Version

Explosive atmospheres - Part 29-2: Gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen (IEC 60079-29-2:2015)

Atmosphères explosives - Partie 29-2: Détecteurs de gaz - Sélection, installation, utilisation et maintenance des détecteurs de gaz inflammables et d'oxygène
(IEC 60079-29-2:2015)

Explosionsfähige Atmosphäre - Teil 29-2: Gasmessgeräte - Auswahl, Installation, Einsatz und Wartung von Geräten für die Messung von brennbaren Gasen und Sauerstoff
(IEC 60079-29-2:2015)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 31/1169/FDIS, future edition 2 of IEC 60079-29-2, prepared by IEC TC 31, Equipment for explosive atmospheres, was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60079-29-2:2015.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2016-01-20
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2018-04-20

This document supersedes EN 60079-29-2:2007.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 60079-29-2:2015 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60079-14	NOTE	Harmonized as EN 60079-14.
IEC 60079-20-1	NOTE	Harmonized as EN 60079-20-1.
IEC 61326-1	NOTE	Harmonized as EN 61326-1.
IEC 60079-29-3	NOTE	Harmonized as EN 60079-29-3.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60079-0	-	Explosive atmospheres -- Part 0: Equipment - General requirements	EN 60079-0	-
-	-		+A11	-
IEC 60079-10-1	2008	Explosive atmospheres -- Part 10-1: Classification of areas - Explosive gas atmospheres	EN 60079-10-1	2009
IEC 60079-10-2	-	Explosive atmospheres -- Part 10-2: Classification of areas - Combustible dust atmospheres	EN 60079-10-2	-
IEC 60079-13	-	Explosive atmospheres -- Part 13: Equipment protection by pressurized room "p"	EN 60079-13	-
IEC 60079-17	-	Explosive atmospheres -- Part 17: Electrical installations inspection and maintenance	EN 60079-17	-
IEC 60079-19	-	Explosive atmospheres -- Part 19: Equipment repair, overhaul and reclamation	EN 60079-19	-
IEC 60079-29-1 (mod)	2007	Explosive atmospheres -- Part 29-1: Gas detectors - Performance requirements of detectors for flammable gases	EN 60079-29-1	2007
IEC 60079-29-4	-	Explosive atmospheres -- Part 29-4: Gas detectors - Performance requirements of open path detectors for flammable gases	EN 60079-29-4	-
IEC 61285	-	Industrial-process control - Safety of analyzer houses	EN 61285	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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EXPLOSIVE ATMOSPHERES –

Part 29-2: Gas detectors – Selection, installation, use and maintenance of detectors for flammable gases and oxygen

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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International Standard IEC 60079-29-2 has been prepared by IEC technical committee 31: Equipment for explosive atmospheres.

This second edition cancels and replaces the first edition published in 2007. This edition constitutes a technical revision.

This edition includes the following significant changes with respect to the previous edition:

		Type		
Changes	Clause	Minor and editorial changes	Extension	Major technical changes
Addition of group 1 to scope	1		x	
Addition of Open Path Gas Detection	3, 4.6, 5.4, 6.2.3.5, 8.2, 8.6, 8.7. 8.8, 11, A4		x	
Changed “combustible” to “flammable”	Throughout	x		
Addition of specific applications	4.5		x	
Improvements to sampling systems	6.2.3.4, 8.2.3, 8.5, 11.2.2	x		

NOTE The technical changes referred to include the significance of technical changes in the revised IEC Standard, but they do not form an exhaustive list of all modifications from the previous version. More guidance may be found by referring to the Redline Version of the standard.

Explanations:

1) **Minor and editorial changes**	clarification decrease of technical requirements minor technical change editorial corrections

These are changes which modify requirements in an editorial or a minor technical way. They include changes of the wording to clarify technical requirements without any technical change, or a reduction in level of existing requirement.

2) **Extension**	addition of technical options

These are changes which add new or modify existing technical requirements, in a way that new options are given, but without increasing requirements for equipment that was fully compliant with the previous standard. Therefore, these will not have to be considered for products in conformity with the preceding edition.

NOTE These changes represent current technological knowledge. However, these changes should not normally have an influence on equipment already placed on the market.

3) **Major technical changes**	addition of technical requirements increase of technical requirements

These are changes to technical requirements (addition, increase of the level or removal) made in a way that a product in conformity with the preceding edition will not always be able to fulfil the requirements given in the later edition. These changes have to be considered for products in conformity with the preceding edition.

NOTE These changes represent current technological knowledge. However, these changes should not normally have an influence on equipment already placed on the market.

The text of this standard is based on the following documents:

FDIS	Report on voting
31/1169/FDIS	31/1179/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60079 series, published under the general title *Explosive atmospheres*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this standard may be issued at a later date.

INTRODUCTION

Flammable gas detection equipment may be used whenever there is the possibility of a hazard to life or property caused by the accumulation of a flammable gas-air mixture. Such equipment can provide a means of reducing the hazard by detecting the presence of a flammable gas and issuing suitable audible or visual warnings. Gas detectors may also be used to initiate precautionary steps (for example plant shutdown, evacuation, and operation of fire extinguishing procedures).

Equipment may be used to monitor a gas atmosphere below the lower flammable limit in circumstances where accumulation of gas may result in a concentration of the gas/air mixture to potentially explosive levels. Performance requirements for gas detecting equipment for such purposes are set out in IEC 60079-29-1 and IEC 60079-29-4. Guidance for functional safety of fixed gas detection systems are set out in IEC 60079-29-3.

However performance capability alone cannot ensure that the use of such equipment will properly safeguard life or property where flammable gases may be present. The level of safety obtained depends heavily upon correct selection, installation, calibration and periodic maintenance of the equipment, combined with knowledge of the limitations of the detection technique required. This cannot be achieved without responsible informed management.

An additional hazard to life is the toxicity of some gases and of the vapours of all liquids except water. It is not generally appreciated that all flammable vapours are potentially toxic at concentration levels which are very small fractions of their respective lower flammable limits. Equipment covered by IEC 60079-29-1 and IEC 60079-29-4 is not specifically intended for toxic protection, and additional personal protection precautions will normally be needed where personnel could be exposed to toxic vapours.

Portable equipment covered by IEC 60079-29-1 and IEC 60079-29-2 commonly have additional detectors for specific toxic gases and also for oxygen deficiency. Users are cautioned that even mild oxygen deficiency may be due to toxic concentrations of some other gas or vapour, which may not be detectable or adequately detected by the equipment in use.

General requirements for the handbook or manual of any particular flammable gas detection equipment are specified in IEC 60079-29-1 and IEC 60079-29-4. These standards provide some necessary background knowledge on the points mentioned above.

This standard has been specifically written to cover all the functions necessary from selection to ongoing maintenance for a successful gas detection operation. Different clauses are appropriate for different tasks within this range of operations. Each clause has been written as stand-alone as far as practicable. This means that some information is repeated in different clauses but with a different emphasis.

Table 1 gives a broad suggestion as to the most relevant clauses to the typical tasks to be performed.

Table 1 – Typical Tasks and Most Relevant Causes

Tasks	Definitions	Basic information properties of gas and vapours	Measuring principles	Selection of equipment	Behaviour of gas releases	Design and installation of fixed gas detection systems	Use of portable and transportable flammable gas detection equipment	Training of operational personnel	Maintenance, routine procedures General administrative control	Measuring principles (full detail) (normative)	Environmental parameters (informative)
Function (Clause)	3	4	5	6	7	8	9	10	11	Annex A	Annex B
Authorities	+	+++	+++	+	+	-	-	-	+	-	-
General management	+	+++	+++	+	+	-	-	+	+	-	+
Selection	+++	+++	+	+++	+++	+	++	-	+	+++	+++
Design engineering / management	+++	+++	+	+++	+++	+++	-	-	-	+++	+++
Installation engineering / management	+++	+++	+	++	+++	+++	-	-	-	+++	+++
Installation, technical	++	+++	++	++	++	++	-	-	-	+	++
Commissioning	+++	+++	++	+	++	+++	-	++	+	-	-
Operations management	++	+++	++	+	+	++	++	+++	+++	+	+++
Operation training	+++	+++	+	+	+	+++	+++	+++	+++	+++	+++
Servicing / Calibration	+++	+++	-	-	-	++	++	+	+++	++	++
Repair	++	+++	++	-	-	+	+	+	+++	++	-

"+++"	Most appropriate
"++"	Advisable
"+"	Useful
"-"	Not applicable

It should be noted that Clause 5 is a simplified version of Annex A.

This standard makes recommendations on how to establish maintenance and calibration intervals. In certain countries there are mandatory general or industry-specific regulations which must be followed as a minimum requirement.

EXPLOSIVE ATMOSPHERES –

Part 29-2: Gas detectors – Selection, installation, use and maintenance of detectors for flammable gases and oxygen

1 Scope

This part of IEC 60079-29 gives guidance on, and recommended practice for, the selection, installation, safe use and maintenance of electrically operated Group II equipment intended for use in industrial and commercial safety applications and Group I equipment in underground coal mines for the detection and measurement of flammable gases complying with the requirements of IEC 60079-29-1 or IEC 60079-29-4.

This standard is applicable for oxygen measurement for the purpose of inertisation where explosion protection is provided by the exclusion of oxygen instead of measuring the flammable gases or vapours present. A similar application is measuring oxygen when inertising a goaf (mined out) area in an underground coal mine.

This standard is a compilation of practical knowledge to assist the user, and applies to equipment, instruments and systems that indicate the presence of a flammable or potentially explosive mixture of gas or vapour with air by using an electrical signal from a gas sensor to produce a meter reading, to activate a visual or audible pre-set alarm or other device, or any combination of these.

Such equipment may be used as a means of reducing the risk whenever there is the possibility of a risk to life or property specifically due to the accumulation of a flammable gas-air mixture, by providing such warnings. It may also be used to initiate specific safety precautions (e.g. plant shutdown, evacuation, fire extinguishing procedures).

This standard is applicable to fixed installations and transportable equipment. Similarly it is applicable to the safe use of portable equipment. Since much modern equipment of this type also includes oxygen deficiency detection and/or specific toxic gas sensors, some additional guidance is given for these topics.

For the purposes of this standard, except where specifically stated otherwise, flammable gases include flammable vapours.

Mists are not covered by this standard due to measurement techniques currently used.

This standard applies to Group II equipment (i.e. equipment intended for use in industrial and commercial safety applications, involving areas classified in accordance with IEC 60079-10-1) and Group I equipment.

For the purposes of this standard, equipment includes

a) fixed equipment including equipment mounted on a vehicle;
b) transportable equipment; and
c) portable equipment.

This standard is not intended to cover, but may provide useful information, for the following:

a) equipment intended only for the detection of non-flammable toxic gases;
b) equipment of laboratory or scientific type intended only for analysis or measurement purposes;

c) equipment intended only for process control applications;

d) equipment intended for applications in explosives processing and manufacture;

e) equipment intended for the detection of a explosive atmosphere resulting from dust or mist in air.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

IEC 60079-10-1:2008, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

IEC 60079-10-2, *Explosive atmospheres – Part 10-2: Classification of areas – Combustible dust atmospheres*

IEC 60079-13, *Explosive atmospheres – Part 13: Equipment protection by pressurized room "p"*

IEC 60079-17, *Explosive atmospheres – Part 17: Electrical installations inspection and maintenance*

IEC 60079-19, *Explosive atmospheres – Part 19: Equipment repair, overhaul and reclamation*

IEC 60079-29-1:2007, *Explosive atmospheres – Part 29-1: Gas detectors – Performance requirements of detectors for flammable gases*

IEC 60079-29-4, *Explosive atmospheres – Part 29-4: Gas detectors – Performance requirements of open path detectors for flammable gases*

IEC 61285, *Industrial-process control – Safety of analyser houses*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60079-0, as well as the following apply. In addition, since this is intended as a stand-alone standard, certain definitions within IEC 60079-29-1 and IEC 60079-29-4 are repeated below for the convenience of the reader.

NOTE Additional definitions applicable to explosive atmospheres can be found in the International Electrotechnical Vocabulary (IEV), IEC 60050-426.

3.1 Gas properties and other physics

3.1.1
ambient air
normal atmosphere surrounding the equipment

3.1.2
clean air
air which is free from gases or vapours (flammable, toxic or environmentally harmful gases) to which the equipment is sensitive or which influence the performance of the equipment

3.1.3
concentration
amount of the gas or vapour of interest in a specified amount of the background gas or air, expressed in suitable units

Note 1 to entry: Typical units include volume fraction (v/v) (see 3.1.19); molar (moles per mole – m/m); percentage of the LFL of a particular substance; parts per million by volume (ppm); parts per billion by volume (ppb).

3.1.4
dose
total amount of substance absorbed or trapped, proportional to the concentration and the duration of exposure

3.1.5
explosive gas atmosphere
mixture with air, under normal atmospheric conditions, of flammable substances in the form of gas or vapour, which, after ignition, permits self-sustaining flame propagation

3.1.6
explosive range
range of gas or vapour mixtures with air, with concentrations between the lower and upper explosive (flammable) limits

3.1.7
firedamp
flammable mixture of gases, consisting mainly of methane, naturally occurring in a mine

3.1.8
flammable gas
gas or vapour which, when mixed with air in a certain proportion, will form an explosive atmosphere

Note 1 to entry: For the purposes of this standard, the term "flammable gas" includes flammable vapour

3.1.9
flashpoint
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

3.1.10
lower flammable limit
LFL
volume fraction of flammable gas or vapour in air below which an explosive gas atmosphere does not form, expressed as a percentage (see IEC 60079-20-1)

Note 1 to entry: This is also known as lower explosive limit (LEL).

3.1.11
optical radiation
ultra-violet, visible or infrared regions of the electromagnetic spectrum

3.1.12
relative density
density of gas or vapour relative to the density of air at the same pressure and at the same temperature

Note 1 to entry: Air is equal to 1,0.

3.1.13
release rate
quantity of flammable gas or vapour emitted per unit time from the source of release which itself could be a liquid surface

3.1.14
source of release
point or location from which a flammable gas, vapour or liquid may be released into the atmosphere in such a way that an explosive gas atmosphere could be formed

[SOURCE: IEC 60050-426:2008. 426-03-06, modified by removal of Note]

3.1.15
toxic gas
gas that may be harmful to human health and/or the performance of persons due to its physical or physico-chemical properties

3.1.16
upper flammable limit
UFL
volume fraction of flammable gas or vapour in air above which an explosive gas atmosphere does not form, expressed as a percentage (see IEC 60079-20-1)

Note 1 to entry: This is also known as upper explosive limit (UEL).

3.1.17
vapour
gaseous state of a substance that can reach equilibrium with its liquid or solid state in the temperature and pressure range of interest

Note 1 to entry: This is a simplification of the scientific definition, for the purposes of this standard, and merely requires that the substance is below its boiling point or sublimation point at the ambient temperature and pressure.

3.1.18
ventilation
movements of air and replacement with fresh air due to the effects of wind, temperature gradients or artificial means (for example fans or extractors)

3.1.19
volume fraction
v/v
ratio of the volume of a component gas to the volume of the gas mixture under specified conditions of temperature and pressure

Note 1 to entry: This is also known as volume ratio.

3.2 Types of equipment

3.2.1
alarm only equipment
equipment which generates an alarm signal but does not have a meter or output giving a measure of the integral concentration

3.2.2
aspirated equipment
equipment that samples the gas by drawing it to the gas sensor – for example by means of a hand-operated or electric pump

3.2.3
continuous duty equipment
gas detecting equipment that is powered for long periods of time, but may have either continuous or intermittent sensing

3.2.4
diffusion equipment
equipment in which the transfer of gas from the atmosphere to the gas sensor takes place by random molecular movement, i.e. under conditions in which there is no aspirated flow

3.2.5
explosion protected equipment
equipment incorporating a type of explosion protection covered by the IEC 60079 series of standards

3.2.6
explosion protection
measures applied in the construction of equipment to prevent ignition of a surrounding flammable atmosphere by the equipment

3.2.7
fixed equipment
equipment that is intended to have all its parts permanently installed

3.2.8
group I equipment
equipment for mines susceptible to firedamp

3.2.9
group II equipment
electrical equipment for use in places with an explosive gas atmosphere other than mines susceptible to firedamp

3.2.10
portable equipment
spot reading or continuous duty equipment that has been designed to be readily carried from place to place and to be used while it is being carried

Note 1 to entry: A portable equipment is battery powered and includes, but is not limited to:

a) a hand-held equipment, typically less than 1 kg, which requires use of only one hand to operate;
b) personal monitors, similar in size and mass to the hand-held equipment, that are continuously operating (but not necessarily continuously sensing) while they are attached to the user; and
c) larger equipment that can be operated by the user while it is carried either by hand, by a shoulder strap or by a carrying harness; which may or may not have a hand directed probe

3.2.11
sample (sampling) system
equipment which typically draws more than one sample, conditions them as necessary, and presents them to a sensor in aspirated equipment

Note 1 to entry: This usually refers to fixed equipment where multiple samples from different detection points are presented sequentially to one or more sensors;

3.2.12
spot reading equipment
equipment intended to be used for short, intermittent or irregular periods of time as required (typically 5 min or less)

3.2.13
transportable equipment
equipment not intended to be portable, but which can be readily moved from one place to another

3.3 Sensors and detectors

3.3.1
catalytic sensor
sensor, the operation of which depends upon the oxidation (combustion) of gases on an electrically heated catalytic element

3.3.2
electrochemical sensor
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

3.3.3
flame ionisation detector
FID
sensor, the operation of which depends upon the ionization of the gas being detected in a hydrogen flame

3.3.4
flame temperature analyser
FTA
sensor, the operation of which depends upon the change of temperature of a flame by the gas being detected

3.3.5
infrared absorption sensor
sensor, the operation of which depends upon the absorption of infrared radiation by the gas being detected

3.3.6
paramagnetic oxygen detector
sensor, the operation of which depends upon the magnetic properties of oxygen

3.3.7
photo ionisation detector
PID
sensor, the operation of which is based on the ionisation of gaseous compounds by ultraviolet (UV) radiation

3.3.8
remote sensor
sensor that is not integral with the main body of the equipment

3.3.9
semiconductor sensor
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

3.3.10
sensor
assembly in which the sensing element is housed that may also contain associated circuit components

3.3.11
sensing element
part of a sensor that reacts in the presence of a flammable gas mixture to produce some physical or chemical change that can be used to activate a measuring or alarm function, or both

3.3.12
single point sensor
sensor capable of detecting gas at a single point location

3.3.13
thermal conductivity sensor
sensor, the operation of which depends upon the change of heat loss by conduction of an electrically heated element located in the gas to be measured, compared with that of a similar element located in a reference gas cell

3.4 Supply of gas to instruments

3.4.1
measuring point
measurement point
location of a single sensor aspirated by diffusion or by a probe

3.4.2
point detection equipment
detection equipment located at a measurement point

Note 1 to entry: This normally refers to a complete single point sensor, rather than a sampling point, and is in contrast with open path equipment

3.4.3
sample line
means by which the gas being sampled is conveyed to the sensor including accessories

EXAMPLE Filter, water trap.

3.4.4
sampling point
point from which sample is taken in an aspirated equipment

Note 1 to entry: Typically this term is applied to fixed aspirated systems.

Note 2 to entry: Typically the equipment at this point will consist of a filter, but there may be other sample conditioning equipment as well.

3.4.5
sampling probe
separate sample line which is attached to the equipment as required, that may or may not be supplied with the equipment

Note 1 to entry: It is usually short (e.g. in the order of 1 m) and rigid (although it may be telescopic), but it may be connected by a flexible tube to the equipment.

3.5 Signals and alarms

3.5.1
alarm setpoint
fixed or adjustable setting of the equipment that is intended to pre-set the level of concentration at which the equipment will automatically initiate an indication, alarm or other output function

3.5.2
alarm signal
audible, visual, electronic or other signal generated by the equipment when an integral concentration of gas in excess of a preset value is detected

3.5.3
continuous or quasi-continuous sensing
mode of operation in which power is applied continuously to the sensing element and readings are taken continuously or at regular and frequent intervals

3.5.4
fault signal
audible, visual, or other type of output which provides, directly or indirectly, a warning or indication that the equipment is defective or out of adjustment

3.5.5
indicating devices
means for displaying values or states in analogue or digital form

3.5.6
inhibition signal
audible, visual, or other type of output which provides, directly or indirectly, a warning or indication that normal operation has been suspended

3.5.7
intermittent sensing
mode of operation in which the power or flow to the sensor is applied intermittently according to a predetermined cycle and readings taken at the predetermined cycle

3.5.8
latching alarm
alarm which, once activated, requires a deliberate action to deactivate it

3.5.9
safety function
function (inclusive from gas sampling to signal output of the gas detection equipment) to enable the overall system to achieve a safe state.

3.6 Times, checks and equipment behaviour

3.6.1
drift
variation with time of the indication produced by the equipment under normal conditions when monitoring a fixed gas volume fraction, or, in the case of open path, a fixed concentration distribution, (including clean air) under constant ambient conditions

3.6.2
functional check
application of test gas or other means of obtaining a response from the sensor to check its function

Note 1 to entry: This may include the generation of an alarm. This check is performed without adjustments of sensitivity.

Note 2 to entry: This is also known as a “response check” or “bump test”.

3.6.3
initial calibration
first calibration for a specific substance, measuring range and application carried out by the manufacturer before delivery, or on site, before starting the operation

3.6.4
poisons
<for sensors>
substances which lead to temporary or permanent loss of sensitivity of the sensors

3.6.5
recalibration
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

3.6.6
recovery time
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

3.6.7
selectivity
response of the equipment to the gas of interest compared with the response to other gases

Note 1 to entry: If there is high selectivity to the target gas, the results will be less ambiguous and the cross-sensitivity to other gases will be low.

3.6.8
sensitivity
ratio of change produced in the equipment by a known concentration of gas or vapour

Note 1 to entry: Depending on context, this can refer to the minimum change in concentration of gas or vapour that the equipment will detect.

Note 2 to entry: High sensitivity implies that low concentrations can be measured.

3.6.9
span
reading on the normal test gas of the equipment

3.6.10
time of response
tx
time interval, with the equipment in a warmed-up condition, between the time when an instantaneous change between clean air and the standard test gas, or vice versa, is produced at the equipment inlet, and the time when the response reaches a stated percentage (x) of the stabilised signal on the standard test gas

Note 1 to entry: Not applicable to spot reading equipment.

3.6.11
zero gas
gas recommended by the manufacturer which is free of flammable gases, and interfering and contaminating substances, the purpose of which is calibration/adjustment of the equipment zero

3.7 Terms exclusive to open path equipment

3.7.1
albedo
proportion of incident light scattered back from a surface

3.7.2
beam blocked signal
audible, visual or other type of output which provides, directly or indirectly, a warning or indication that the optical path is obscured or that the signal detected is too weak to enable the equipment to function normally

3.7.3
gas calibration cell
sealed enclosure with transparent ends which can be filled with test gases

3.7.4
integral concentration
mathematical integral of the gas concentration along the optical path

Note 1 to entry: It is expressed in units of concentration multiplied by distance, e.g. LFL metre for flammable gases or ppm metre for toxic gases

Note 2 to entry: 100 %LFL x 1 metre = 1 LFL metre;

10 %LFL x 10 metre = 1 LFL metre.

3.7.5
meteorological optical range
MOR
length of path in the atmosphere required to reduce the luminous flux in a collimated beam from an incandescent lamp, at a colour temperature of 2 700 K to 5 % of its original value

3.7.6
open path
optical path which traverses the area (or part of the area) in which the atmosphere is being monitored and through which gases in the atmosphere are free to move

3.7.7
optical axis
median line of the optical path

3.7.8
optical path
path traversed by optical radiation from an optical transmitter to an optical receiver

Note 1 to entry: The radiation may traverse the path once, twice or many times depending on the form taken by the instrument

3.7.9
receiver
assembly in which the optical detecting element(s) are housed and which may contain associated optical and electrical components

3.7.10
retroreflector
individual or multiple arrangement of reflecting corners of cubes arrayed so that light is reflected back parallel to its incident path

3.7.11
gas detection transmitter
fixed gas detection equipment that provide a self-conditioned electronic signal or output indication to a generally accepted industry standard (such as 4-20 mA or relay), intended to be utilized with separate gas detection control units or signal processing data acquisition, central monitoring and similar systems, which typically process information from various locations and sources including, but not limited to gas detection equipment

3.7.12
transceiver
assembly in which the optical detecting element(s) and optical transmitting element(s) are housed and which may contain associated optical and electrical components

3.7.13
transmittance
fraction of luminous flux which remains in a single beam after traversing an optical path of a given length in the atmosphere

3.7.14
transmitter
assembly in which the optical transmitting element(s) are housed and which may contain associated optical and electrical components

4 Basic information on the properties, behaviour, gases and vapours, and specific applications of gas detection

4.1 Detecting gases and vapours

4.1.1 General

For the purposes of Clause 4, a distinction is drawn between gases, which remain gaseous at typical ambient pressures and temperatures, and vapours where liquid can also exist at any relevant pressure or temperature.

Effective operation of flammable gas detection equipment depends not only on its performance but also on its correct usage.

Equipment capability, and its suitability for the intended application and the user's knowledge of its limitations, both generic relating to sensor technology, and individual relating to its other design features, cannot alone ensure that its use will properly safeguard personnel, areas, or locations where flammable gases or vapours may be or are present. The level of safety obtained also depends upon the user having a basic knowledge of gas and vapour properties and phenomena.

This knowledge should enable the user to determine whether the gases are heavier or lighter than air, and whether the vapours are heavier than air or of similar density, and therefore where they may accumulate. If the direction and velocity of air movement is known, it can be seen how they may propagate. In addition, there may be physical or chemical reasons imposing limitations on a particular application, such as calibration considerations.

Consideration shall be given not only to those gases and vapours that are required to be detected, but also to those gases and vapours that are not required to be detected, but may also be present.

The effects of humidity and temperature variations may need to be evaluated, particularly when sampling lines are used, and, more importantly, if vapours other than water are involved.

Small environmental changes, such as a rise or fall in temperature, which may be ignored for most purposes, can significantly modify conditions, particularly if liquids are present and produce increased amounts of vapours, or if vapours condense as fogs or inside the equipment itself.

Failure to take these properties of gases and vapours into account at any of the stages of selection, installation, commissioning, training, operation and on-going maintenance of even the simplest of equipment can result in the production of erroneous readings. These in turn can lead on one hand to false alarms or incorrect action, and on the other hand to failure to alarm or failure to take any appropriate action. Such factors can unnecessarily endanger lives and property.

Some gases or vapours can cause corrosion or other deterioration to certain types of sensors. Some types of sensors have specific lifetimes. The sensitivity can change over time. This applies to certain types of sensors for toxic gases and oxygen deficiency as well as for flammable gases and vapours. This is the major reason for requiring frequent functional checks of some of the more common types of flammable gas detectors. It is usually done using a test gas or calibration gas applied in a specified way. The correct test/calibration equipment for one type of gas detection equipment may not be appropriate to another type, and some training will usually be needed.

Although a mixture that has a concentration above the upper flammable limit is not explosive, it should be realised that on dilution with air it will become explosive, and so it is advisable to consider it as explosive. It should also be noted that it will normally be toxic at much lower concentrations.

4.1.2 Safety when monitoring for flammable gases where personnel could be present

Personnel should frequently observe the reading on any gas detection apparatus when entering a potentially hazardous area. The area may already contain asphyxiates or flammable gas and the personnel may need expedient warning of this danger.

The equipment will only give a reading for the location where the reading is being taken, or the location of the end of the sampling line if a sampling line is being used. A hazardous atmosphere may be building up a few metres from the sampling point. Therefore, many gas tests shall be done all around the intended area of work to ensure that no pockets of hazardous gas or vapour are present in the work area.

If vapours are likely to be present, some of the tests should be done one or two centimetres from the floor. This might detect a small problem (e.g. a minor liquid leak) at an early stage. All nearby low spots should be tested.

The readings are only valid for the time they are taken. Circumstances change. Frequent readings are recommended, particularly if vapours (see 4.3.3) could be involved and the temperature is rising.

Where a wide range of gases and vapours could be encountered in the work area there will be a range of potential sensitivities. A low ‘alarm point’ or ‘action point’ will therefore be required.

If there is a chance of sensor ‘poisons’ (such as silicones, leaded petrol, acids, etc.) being present, the sensitivity of an equipment using catalytic or semiconductor sensors should be checked at frequent intervals.

While the atmosphere is being monitored for concentrations of flammable gases and vapours, consideration should also be given to the fact that many of these, including all vapours except water, are also toxic to personnel. Additional detectors for the specific gases and vapours and additional precautions may be needed.

If a flammable gas or vapour detection equipment is also equipped with high sensitivity sensors for specific toxic gases it should be realized that they may only detect these specific gases. They will not usually detect other toxic materials.

Closely allied to flammable gas monitoring is monitoring for oxygen deficiency and this is detailed in 4.4.1. Frequently this feature is added to the equipment. There are several possible reasons for an oxygen deficiency. Some of them are due to situations where a toxic substance is part of the cause of the deficiency, and these are of far greater concern. Again, additional detectors and precautions may be needed.

Therefore, when about to work in a hazardous area, it is advisable to specifically check on the potential toxicity of the atmosphere with the plant safety officer, industrial hygienist, or equivalent and a gas detector that covers the possible range of flammable, and toxic materials in the area should be chosen.

NOTE Different countries have different systems, and can use different values, for describing maximum safe levels of potentially toxic substances. For typical details, consult the USA's ACGIH book of TLV's (Threshold Limiting Values) and BEIs (Biological Exposure Indices), or the European Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area who publish a list of recommended TLV's. Both organisations update these publications annually. Other countries usually employ one or the other of these sets of data as a basis for their national documents, which can also be referred to.

4.2 Some common properties of gases and vapours

All gases and vapours will fully mix with all others by diffusion over time or if stirred. They will not separate out. However, some gases and vapours may react chemically with each other on mixing.

If a gas or vapour concentration is increasing in an area it is because more of that substance is being released. It is not due to settling out.

Once gases and vapours have been mixed, they will stay mixed, unless a component is removed chemically, or is absorbed (for instance on a charcoal filter). Additionally, in the case of vapours, removal can be by condensation due to increased pressure and/or falling temperature.

The density of pure gases and the effective density of vapours is proportional to their molecular mass. There is no significant change of volume on mixing gases and vapours. Therefore the density of mixtures of gases and vapours may be simply calculated from the volume fractions and molecular masses of their components. If relative density data is available, the relative density can be similarly calculated from the volume fractions and relative densities of the components.

Air has an equivalent molecular mass of approximately 29, corresponding to a relative density of 1. For instance, gases with lower molecular masses than 29 will have a relative density less than 1 and will be lighter than air.

As an example, methane with a molecular mass of 16 will be lighter than air, carbon dioxide with a molecular mass of 44 will be heavier than air. A mixture of the two, for instance a land fill gas or a mine seam gas, with approximately 53 % methane and 47 % carbon dioxide will have a similar density to air.

Mixtures of clean air with pure or mixed gases that are lighter than air, will still be lighter than air, but less so, proportionately to their volume fractions. They will tend to rise until they become so diluted with clean air that the effect becomes negligible.

Mixtures of clean air with gases or vapours that are heavier than air, will still be heavier than air, but less so. They will tend to flow into low spots; pits, trenches etc, until they become so diluted with clean air that the effect becomes negligible.

If a source of release and its surrounding air is substantially hotter than the ambient air the released mixture can rise initially, even if the relative density at the ambient temperature is greater than 1. As a rule of thumb, a temperature rise of 30 K will overcome what by calculation would be 10 % greater relative density than air. The converse applies where the release is colder than the ambient temperature.

Because of temperature differences at release and normal turbulence, gases and mixtures with relative density between 0,8 and 1,2 generally can be considered as having a similar relative density to air, and therefore are capable of propagating in all directions.

All flammable gases and vapours will have an LFL and a UFL. The LFL and UFL are experimentally determined, and this data for many substances can be found in IEC 60079-20-1. These values cannot be predicted with any accuracy.

NOTE Because this is experimental, different countries specify different values for LFL and UFL values, which have a legal standing. As two examples:

- NFPA 30 is a publication used within the USA.
- GESTIS is a publicly available database used within Germany.

All vapours, except water vapour, are toxic to varying extents. All flammable vapours are toxic at levels well below 25 % of LFL, most are toxic below 1 % of LFL. At best, gases (except air or oxygen) are asphyxiants (i.e. their effect on personnel is only due to them diluting the oxygen content of the air). Other gases vary from mild to extreme toxicity.

NOTE An asphyxiant is a non-toxic or very mildly toxic and (mostly) inert gas which works by displacing oxygen in the lungs. A toxic gas may cause significant acute health effects even at low concentrations.

When detecting specific gases or vapours, it is necessary to be aware of the potential toxicity of other gases or vapours that might be present, but are not being detected.

4.3 The differences between detecting gases and vapours

4.3.1 General

The major practical differences between the detection of gases and the detection of vapours are outlined below.

4.3.2 Detection of gases

4.3.2.1 General

Substances that remain gaseous under the range of temperatures and pressures relevant to the gas detection application will closely follow the Gas Laws and behave predictably. Basically, simple training may be adequate.

Gases may be pure, or any mixture of gases can be made, unless they react chemically. The composition of non-reacting gas mixtures does not change with temperature or pressure.

4.3.2.2 Calibration considerations

Accurate calibration requires calibration gas recommended by the manufacturer for calibration/adjustment purpose which usually contains the target gas in a known concentration with a tolerance of less than 5 % relative. For functional checking, a test gas with reduced accuracy may be used. The manufacturer's recommendations for functional checking of sensors should be followed.

Kits for routine calibration and functional checks of single point sensors, and portable and transportable equipment usually consist of a portable cylinder of a compressed gas, some form of flow control and an adapter to fit the gas detection equipment. In the case of multipoint sampling systems, larger cylinders may be used close to the central equipment, and even permanently connected for automatic calibration.

It is possible to make and store under high pressure, calibration and other test gas mixtures fully representative of the intended gas detection application. Many can be made with a dry or synthetic air as balance gas. This is essential for catalytic sensors and others that require air as balance gas in order to operate correctly. However there are safety limits for in compressing gas mixtures that have a volume fraction of more than 50 % LFL.

The more-reactive gases tend to have longer storage life if the balance gas is specially dried nitrogen, and this is normally chosen unless it is incompatible with the sensor.

In order to calibrate open path equipment, a cell with optical windows at both ends containing a calibration gas has to be interposed in the optical path. In order to have practical dimensions for these cells, concentrations of the flammable gas are needed at volume fractions well in excess of the LFL concentrations if they use air as balance gas (see also 4.5). Fortunately the infrared detection principle permits nitrogen to be used as the balance gas, and so the calibration gas may be compressed safely.

Where more than one flammable gas (or vapour) may need to be detected, it is common to use a single calibration or test gas, and relative response data. For further details see 4.3.3.2.

For calibration gas cylinders the minimum storage temperature specified by the calibration gas manufacturer has to be followed to avoid condensation.

4.3.2.3 Propagation and sampling considerations

Gases can have a density that is lighter than air, such as hydrogen and methane. They can have approximately the same density as air, such as carbon monoxide, hydrogen sulfide, hydrogen cyanide, ethane, ethylene and acetylene; or they can have a density heavier than air such as chlorine, carbon dioxide, sulfur dioxide, LPG, propane, propylene and butane.

When sampling, at least some tests or readings should be taken in locations with the density of the gas in mind. This may also help to detect the source of release.

4.3.2.4 Toxicity considerations

Some flammable gases (specifically ammonia, hydrogen sulfide, hydrogen cyanide, carbon monoxide, methylamine and formaldehyde) are highly toxic at levels which are so low as to be undetectable by conventional flammable gas equipment, although they are listed in IEC 60079-20-1 and can be detected by such equipment at the much higher levels relevant to detection in LFL ranges. If these gases are likely to be present they will require separate and specific toxic gas sensors, and possibly other precautions, if personnel can be in the area.

Also it is necessary to be aware that some non-flammable gases are highly toxic, such as chlorine, sulfur dioxide, nitric oxide and nitrogen dioxide. If these gases are likely to be present they will require separate toxic gas sensors, and possibly other precautions.

Other flammable gases such as propane, butane and LPG are mildly toxic or narcotic at levels well below their LFL. Similarly non-flammable gases such as carbon dioxide and nitrous oxide are potentially toxic at levels that may not result in a significant oxygen deficiency (see 4.4.4).

4.3.2.5 Water vapour

Although this subclause relates only to detecting gases, it is not normally possible to ignore water vapour. This can produce problems in cold equipment that have been suddenly exposed to a hotter and humid atmosphere. Examples of this situation are in leaving a cold store and entering a normal atmosphere, or in leaving an air-conditioned situation and entering into a humid tropical or sub-tropical atmosphere. Water can condense in or on a sensor, causing a temporary loss of sensitivity or some other problem, until the equipment warms up and the water re-evaporates. This is particularly the case with electrochemical sensors: A very rapid drop in an oxygen reading can occur from a normal 20,8 % or 20,9 % reading to 16 % or lower, due only to a coating of water condensing onto the cold sensor membrane. The sensitivity may then only recover slowly over some minutes as the sensor warms up to ambient, and the film evaporates.

Water vapour may also cause significant deviations of the reading of several types of sensors (see Clause 5 and Annex A).

4.3.3 Detection of vapours

4.3.3.1 General

Vapours are more difficult to understand than gases. Substances, where the liquid or solid can coexist with their gaseous state at normal or slightly abnormal temperatures and pressures are said to have vapours. Vapours behave differently than gases, and can present more problems. Where vapours are likely to be found, additional training in their properties is required.

Where a liquid is present, the rate of evaporation and the maximum volume fraction of the vapour (saturated vapour) will increase with temperature and falling pressure. The evaporation rate is dependent on the size of the surface of the liquid but independent of the quantity of liquid, provided there is some liquid remaining. The maximum volume fraction of the vapour is also independent of the background gas provided it is at the same temperature and pressure, and is not soluble in the liquid.

The volume fraction that can be reached by the vapour at any temperature is inversely proportional to the absolute pressure. So an increase in pressure can cause condensation.

As a rule of thumb, at constant pressure, the maximum (saturated) volume fraction of any vapour will increase by a factor between 1,5 and 2,0 for each 10 K rise in liquid temperature, and will fall by a factor of 1,5 to 2,0 for every 10 K reduction.

The effect of doubling the absolute pressure has an equivalent effect to a decrease in temperature of 10 K to 17 K at constant pressure. Halving the pressure has an effect equivalent to a similar rise in temperature.

The temperature at which the saturated volume fraction can reach 100 % at the prevailing pressure is the boiling point.

It is only possible to have 100 % volume fraction of a vapour at or above the boiling point at that atmospheric pressure. Below the boiling point of the liquid, the maximum possible concentration of vapour in air or other gases must be less than 100 % volume fraction.

The actual amount of vapour will be less than the amounts predicted above if clean atmosphere is being continually passed over the liquid surface, or if there has not been enough time for equilibration to be established. However this maximum amount can be achieved in an enclosed space, particularly if it has been closed for some time and the air space is slowly stirred by convection or mechanical means.

Flammable liquids have flashpoints, which are determined in a different way from LFL, but are essentially the temperatures at which their vapours can reach their LFL volume fractions in the air above their liquid surfaces, again provided that the vapour is not continuously removed by air currents.

All of these points impose limits on mixtures of vapours with gases. For any particular volume fraction of a vapour in a mixture with gas, a fall in temperature or increase in pressure will, at a certain stage, reach the saturation point, below which liquid will start to condense as a fog or liquid. When applied to water vapour this is known as the “dew point”. This term is frequently applied to other vapours. Below the dew point the composition of any vapour-gas mixture must therefore change. If this happens within the gas detection system or on the gas sensor, this can lead to falsely low readings on the condensing sample. Also, after such condensation has occurred there will be re-evaporation on returning to cleaner air which will give false high readings.

4.3.3.2 Calibration considerations

Apart from the limitations for gas mixtures in 4.3.2.1., real restrictions on what calibration or test vapours are practical for field use are imposed by the minimum temperature at which they will be used, and the required pressure in a calibration gas or test gas cylinder.

Test kits with a stored pressure in the range 2 MPa to 3 MPa are effectively limited to around 50 % LFL for n-pentane (boiling point 36 °C), about 10 % LFL for n-hexane (boiling point 68 °C), rather less for other substances with similar boiling points, and lower values still for substances with higher boiling points.

Generally, pentane and hexane test gases are directly applicable to the petroleum industry where such vapours can be the main components. However, for other industries, it is seldom possible to make a portable or transportable calibration or test kit for use outside a laboratory that is truly representative of the vapour to be measured.

To get around this problem, responses of the equipment to different gases and vapours with reference to a particular practical test gas or vapour are determined in a laboratory. Such data is time-consuming and expensive to obtain, and for general purposes is normally only done for a particular model of equipment, not for each unit. In such cases there will be variations between different units.

Routine calibration is then effected in one of two ways:

a) to give a correct LFL readout on the calibration gas or vapour and use the relative response data directly for the substance(s) of interest (or generate the relative response in software);
b) to give an artificial LFL readout on the calibration gas or vapour so that the LFL readout will be approximately correct when exposed to the gas or vapour of interest, or to a specified range of gases or vapours.

There can also be variations in relative responses of sensors over time, particularly in the case of sensors which have a limited life, or are susceptible to “poisoning” (loss of sensitivity due to chemical action), such as electrochemical and catalytic sensors.

For instance, in the case of catalytic sensors, the response to methane will selectively deteriorate before other gases or vapours. If this happens and the equipment can be successfully re-calibrated on methane, it will over-read on all other substances, which is in the safe direction.

For this reason, in all catalytic combustion applications where methane could be involved, the use of methane test gas is recommended for functional checks and during calibration procedures, even if some other gas or vapour is the target gas. Otherwise propane, butane, pentane, or hexane calibration mixtures are usually recommended, for the reason that sensitivity to these will tend to fall before most other substances.

It should also be noted that the sensitivity of catalytic sensors to methane in LFL terms is generally higher than the sensitivity to other substances except hydrogen. Consequently, if using the technique described in a) above, the alarms should be set to a lower set point, and if using the technique described in b) the calibration reading should be set to a correspondingly higher reading than the %LFL of the methane test gas.

Hydrogen is to be used as calibration gas only for applications where hydrogen is the only target gas.

Whenever test or calibration gases other than the gas or vapour of interest are used, it is recommended that additional safety margins, lower alarm settings etc. are employed in order to compensate for the added uncertainty of relative response data due to the factors mentioned above.

4.3.3.3 Propagation and sampling considerations

Only the vapour of water is lighter than air. There are only four vapours, three of which are flammable, with a similar density to air (methanol, hydroxylamine, hydrazine and hydrogen peroxide, the last three being uncommon).

All other vapours are more dense than air. Most are considerably more dense than air. At a point of release, unless heated, they will initially flow downwards or across level surfaces, and until they are well mixed with air they will stay close to the ground, possibly only a few centimetres deep, which is where they will present the greatest flammability problems. A severe instance of this is in the case of pits, trenches and tunnels which will tend to fill from the bottom upwards and can permit extensive propagation over hundreds of metres. This can also cause the most serious toxicity problems for personnel entering pits and tunnels.

When sampling for flammable vapours in relatively undisturbed atmospheres, some tests should be performed at very low levels, ideally within a centimetre of the floor or ground.

Once mixed with an excess of air, all vapours will be found at all levels, possibly at volume fractions well below their LFL but still presenting major toxicity problems

The vapour of a high flashpoint flammable liquid may not be detectable if the ambient temperature is well below the flashpoint. As an example, using the rule of thumb at the beginning of 4.3.3, if the ambient is 60 K below the flashpoint, it can be estimated that the vapour can only reach between 1 % and 8 % of LFL as a maximum, and then only slowly, close to the liquid, and if the vapour is not being blown away.

Conversely, if the temperature rises, and particularly in an enclosed area, the concentration can change dramatically. Again, using the rule of thumb, the vapour concentration in an enclosed space could increase by a factor up to eight for a 30 K rise in temperature, caused, for instance, by the sun on an external tank. A previously undetected amount of vapour while the tank was cold could become very significant when it is heated up. When temperatures are rising, frequent vapour testing is necessary.

Other problems can arise with substances of high molecular mass. The higher the molecular mass is, the lower the rate of diffusion will be. This applies to non-pumped equipment where diffusion screens are used to prevent external ignition, and also within certain sensors. In particular this can adversely affect both the speed of response and the sensitivity in catalytic sensors.

Major problems also arise in vapour testing due to the possible condensation of the sample itself in the detector or its accessories: Gas detectors will only detect the gases or vapours present. They will not detect mists or condensed liquids caused as a result of the equipment, or a sample line, being markedly colder than the atmosphere being sampled.

If this happens within the gas detection system or on the gas sensor, this can lead to falsely low readings on the condensing sample. Also, after such condensation has occurred there will be re-evaporation on returning to cleaner air which will give false high readings. (see 4.3.3.1)

4.3.3.4 Toxicity considerations

All vapours except water, including all non-flammable ones, are toxic to some degree. All flammable vapours are toxic at concentrations well below LFL. Most vapours, including many commonly found in industry, are of toxic concern well below 1 % of LFL. Therefore they may be undetectable at concentrations where they are already a toxic problem if only using a flammable gas detector with a normal LFL range. Additional precautions are needed.

4.4 Oxygen deficiency

4.4.1 General

Fixed or portable oxygen detectors are essential for work in locations such as confined spaces and underground coal mines. Portable apparatus typically combine oxygen with flammable gas sensors and frequently also with toxic sensors.

Some varieties of oxygen sensors respond to changes in pressure, and so need checking in clean air, and possibly adjusting, each time they are used and / or if there is a significant change of altitude, such as ascending a tall structure or descending in a mine shaft.

The volume fraction of oxygen in dry air is about 20,9 % v/v. A typical oxygen deficiency alarm setting is between 17,0 % to 19,5 % v/v.

Taking as an example a setting of 19,0 % v/v, the alarm should operate on a 1,9 % v/v deficiency or, put another way, a deficiency of 10 % of the original concentration. In certain circumstances (presence of toxic gases) this may not be adequate for personnel protection.

Similarly, with a setting of 19,5 % v/v, the alarm should operate on a 1,4 % v/v deficiency or, put another way, a deficiency of 7 % of the original concentration. In certain circumstances this also may not be adequate for personnel protection on its own.

In many applications the use of a combined apparatus for flammable gases and oxygen deficiency may not provide sufficient information for the operator. Oxygen deficiency may be due to the presence of a toxic gas. In this case, additional detection for toxic gases is required.

There are three basic physical and chemical mechanisms by which oxygen deficiency can occur, described in 4.4.2 to 4.4.4 with reference to the 19,5 % v/v alarm setting example above.

4.4.2 Chemical reaction of oxygen, with solid products

The main examples are the rusting of steel or the corrosion of other metals. Oxygen has simply been subtracted from the air, and a solid oxide is left. This can typically happen in confined spaces constructed of metal.

When the alarm operates at 19,5 % v/v, the atmosphere is equivalent, in physiological terms, to working at an altitude about 650 m higher than the current altitude. Normally this will not cause any health problem to personnel.

4.4.3 Chemical reaction of oxygen, with gaseous products

In the simplest case this could be the result of respiration, aerobic bacterial action (but not anaerobic action), or clean combustion. The 1,4 % reduction in oxygen content needed to set off the alarm would be accompanied by an increase in carbon dioxide level of about 0,8 %, which is fairly safe in the short term, and there would be no short-term or long-term effects on a ‘normal person’.

If, however, the oxygen deficiency was the possible result of ‘dirty’ combustion involving wood, paper, coal, oil, etc, then, even after the smoke had settled, an atmosphere with 19,5 % v/v oxygen remaining could be lethally toxic due to amounts, possibly in excess of 0,2 % v/v (2 000 parts per million), of carbon monoxide produced together with the carbon dioxide.

If the combustion had also involved plastics such as PVC, polyurethane etc, the atmosphere would be very toxic due to additional combustion products such as hydrogen chloride and hydrogen cyanide.

4.4.4 Dilution of the air by displacement by some other gas or vapour

Detection of a gas by oxygen depletion is only recommended under very controlled conditions and is not otherwise recommended.

The 1,4 % v/v oxygen deficiency needed to cause the alarm would require an addition of 7 % v/v of the other gas or vapour. Thus the problem becomes that of knowing what gas or vapour has caused the deficiency. There are several categories:

a) Inert gases; not toxic

   These are further described in the following paragraphs:If the cause of the oxygen deficiency is dilution by one of the inert gases such as nitrogen, argon, helium or neon, (or water vapour) an addition of 7 % v/v or a limited amount more of the inert gas to the atmosphere is perfectly safe. The situation is similar to that in 4.4.2.

   NOTE There are areas where the volume fraction of oxygen is controlled at levels between 12 % v/v and 15 % v/v by dilution in this way, to minimise the risk of fire. These areas will be entered in some cases by personnel. If portable oxygen detectors will be used to protect the personnel the alarm levels for the devices have to be specifically adjusted in relation to the oxygen level in those areas. In such cases, for areas with low volume fractions of oxygen personnel have to pass a medical test according to national regulation before being allowed to enter such areas.

b) Flammable gases; not toxic

   If the gas causing the oxygen deficiency is hydrogen, methane (natural gas) or ethane, the atmosphere would be safe to breathe for a short period but would be above the LFL, and therefore explosive. But if there was a flammable gas detector as well as the oxygen detector, it should have given an alarm well before this dangerous situation occurred.

c) Flammable gases; toxic

   If the gas causing the oxygen deficiency is acetylene, ethylene, propane, LPG or butane, breathing the atmosphere would be lethal within a few seconds at least. But it would be above the LFL. So if there was a flammable sensor as well, this would alarm first.

d) Non-flammable; toxic

   Oxygen deficiency measurement should never be used for the detection of toxic gases

   WARNING – Oxygen detectors shall never be used to indicate displacement by CO_2.

   Reliance on oxygen detectors to monitor the presence of carbon dioxide has led to fatalities.

4.5 Specific applications of gas detection

4.5.1 Gas detection as means of reducing risk of explosion

4.5.1.1 General

Flammable gas detection equipment in various combinations of operation may provide means to reduce the probability of an explosion by eliminating sources of ignition (i.e., non-explosion protected equipment that may be located in an area that may be exposed to explosive gas atmosphere) or by activating safety functions to keep flammable gas concentration below 25 % LFL.

In major accidental gas releases, an explosive gas atmosphere is likely to be present beyond the limits of an area classification; and, measures should be taken to eliminate sources of ignition within such areas.

The safety function(s) to be employed by means of gas detection and subsequent actions are:

a) the disconnection of any non-explosion protected equipment if the set alarm level is exceeded,
b) increased ventilation rate to prevent increase of gas concentration to above 25 % LFL at the equipment location,

c) to provide a shutdown signal to the Safety System where detection of flammable gas indicates a loss of containment,
d) for rooms protected by pressurisation, closure of ventilation dampers to prevent ingress of gas. See also IEC 60079-13 regarding isolation of non-explosion protected equipment inside the room,
e) for analyser houses, a broad range of provisions as described in IEC 61285, where gas detectors are an important part.

This main alarm level should be at or below 20 % LFL.

In all cases of detection of flammable gas levels at or above 20 % LFL, audible and visual annunciation should be initiated.

Indication of low levels of flammable gas (with or without pre alarm) should be used to:

1) initiate troubleshooting and repair activities,
2) activate operation of a ventilation system, to increase the rate of existing ventilation to avoid the disconnection of non-explosion protected equipment, and
3) shutdown processes due to more severe gas leaks which may cause the exceeding of the main alarm level.

The equipment for the detection of flammable gas should comply with the performance requirements of IEC 60079-29-1 or IEC 60079-29-4 for the gas or vapour likely to be present in the ventilated area.

4.5.1.2 Ventilation Rates

Ventilation and air movement has two basic functions:

a) To increase the rate of dilution and promote dispersion to limit the extent of a gas hazardous area;
b) To avoid the persistence of an explosive atmosphere which may influence the type of a Zone

If the ventilation rate is calculated such that gas-air mixtures in concentrations exceeding 25 % of the LFL will not occur this high ventilation rate is the relevant means of protection. Gas detection is not mandatory but is recommended to ensure a high level of safety should the ventilation system fail.

If ventilation rates are considered as low ventilation then a combination of ventilation and gas detection is the means of protection and the recommendations provided should be followed.

All ventilation rates are to be compared with expected flammable gas leakage rates, under various conditions of operation. The relative comparison of ventilation rate to flammable gas leakage rate will determine the manner in which combination flammable gas detection equipment and ventilation should be operated.

Guidance for the assessment of ventilation efficiency and availability can be found in IEC 60079-10-1:2008, Annex B.

4.5.1.3 Gas detection in “high” ventilated areas

In this type of application the primary protection against the accumulation of flammable gas concentrations is by high ventilation. The ventilation rate is calculated such that it is ensured that significant quantities of vapour-air or gas-air mixtures in concentrations exceeding 25 % of the LFL will not occur except in the dilution area.

The ventilation rate should be calculated based on maximum leak rates expected.

The detection of flammable gases is an additional means of protection should the ventilation system fail.

If ventilation fails (a fault condition) disconnection of non-explosion protected ignition-capable equipment should occur.

4.5.1.4 Gas detection in “medium” ventilated areas

If a maximum leak rate cannot be predicted, an adequate ventilation rate may be calculated by assuming leak rates to be expected as realistic. For those leak rates vapour-air or gas-air mixtures in concentrations exceeding 25 % LFL is controlled, resulting in a stable zone boundary, at the ventilation rate determined. However it cannot be excluded that higher leak rates may occur and then the ventilation as the only means of protection will not be sufficient.

Minimum ventilation rates and the ventilation arrangement to be considered must be sufficient to prevent accumulation of flammable gas in corners or behind equipment.

When used in conjunction with medium ventilation rates, equipment for the detection of flammable gases provides an additional level of protection in an area and does form part of the primary safety concept. Gas detection should provide means to cause increase of the ventilation rate at gas concentrations at or below 20 % LFL. If the increased ventilation fails to reduce the vapour-air or gas-air mixtures then the main alarm shall activate the safety function to disconnect all non-explosion protected equipment.

Depending on the local conditions an increase of ventilation should be started at pre-alarm levels between 5 % LFL and 20 % LFL.

If one of the means fails (gas detection or ventilation) the fault has to be indicated. Ignition-capable equipment, can be permitted to operate for a short period if immediate loss of power or automatic shutdown would result in a more hazardous situation, provided repair is initiated and the other means is working correctly.

4.5.1.5 Gas detection in low ventilated areas

Ventilation rates which are so low that they will not prevent the accumulation of flammable gas levels above 25 % LFL are considered as “low” ventilation. In case of low ventilation the degree of dilution may be so low that the classification of the area has a lower Zone number than might otherwise be applied for the grade of release (i.e. a Zone 1 hazardous area from a secondary grade source). Permanent and continuous monitoring of the gas concentration with fixed gas detectors may justify the use of equipment with a lower equipment protection level (EPL) than normally required

For such application both ventilation and gas detection are used as means of protection. Alarm levels and actions (increase of ventilation and disconnection of non-explosion protected equipment) should be the same as in 4.5.1.4.

4.5.1.6 Gas detection in ventilated areas using recirculation

Reduced outside air exchange (below determined adequate ventilation rates) may be used where recirculation of inside air is employed, provided all the following criteria are observed:

1) The area is monitored continuously by a gas detection system for flammable gases.
2) Flammable gas detection is provided in the return air of the ventilation system.
3) When the air inlet flow is reduced, the inside air distribution is maintained by the recirculation.
4) The gas detection system will stop the recirculation when exceeding the lowest alarm level (less than 20 % LFL) and increase the ventilation rate for outside air.

5) The outside air exchange is provided at a rate that will maintain flammable gas levels below 25 % LFL.
6) At the main alarm level at or below 20 % LFL the non-explosion protected equipment shall be disconnected.
7) If the ventilation fails the fault has to be indicated but no disconnection of equipment is required, provided repair of the ventilation system is initiated and the gas detection system is working correctly.

4.5.2 Gas free work permit

4.5.2.1 General

In hazardous areas equipment that uses an acceptable method of protection that is required to be temporarily bypassed for maintenance or trouble-shooting, may be operated under a gas free work permit. The work may be performed in a hazardous area with the method of protection bypassed under the gas free work permit provided additional equipment for the detection of flammable gas is used and monitored by trained personnel.

NOTE The equipment for the detection of flammable gas can be of portable, transportable or fixed point type detection.

For the maintenance or repair work carried out in a hazardous area, any portable ignition capable devices or equipment (e.g. arc welding equipment, not suitable for the hazardous location) may be operated, according to the work permit instructions and while the equipment for the detection of flammable gas is used and monitored by trained personnel.

The additional equipment for the detection of flammable gas should be suitable for the use in the hazardous area where the work will take place (compliance with IEC 60079-0 and relevant other parts) and should comply with IEC 60079-29-1 for performance for the gas or vapour likely to be present in the working area.

4.5.2.2 Operation

Additional equipment for the detection of flammable gas used to monitor local conditions as a general indication of the presence of flammable gas at the place and time that the permitted work is being performed should be capable of and calibrated for detection of the flammable gas likely to be present in the working area during the time that the permitted work is being performed.

For maintenance and/or repair work of equipment carried out in hazardous areas where the method of protection is bypassed, the following actions should be taken:

a) All portable/transportable gas detection systems should be checked for functionality with a known concentration of flammable gas just prior to use in conjunction with a gas free permit (bump test).
b) Initial measurements should be taken to confirm the absence of any flammable gas throughout the work area.
c) Continuous monitoring should be used to confirm the continued absence of a flammable gas or vapour.
d) Monitoring equipment should be used and monitored by properly trained personnel.
e) During any maintenance activity additional and adequate operational procedures should be in place to ensure that the personnel responsible for the emergency response and actions taken when gas presence is detected is able to carry out their duties correctly.

Before the gas free work permit will be given out the points a) and b) should be carried out successfully to certify that a work location is gas free before the method of protection will be bypassed and before the introduction of sources of ignition into that work area will be allowed.

4.5.3 Monitoring of air inlets

Where ventilation air, free of ignitable concentrations of flammable gases or vapours is required (eg. for an air intake for a pressurised room which is located in a hazardous area or internal combustion engine) which is located near areas that may contain explosive gas atmospheres, gas detection to monitor the air inlet should be installed. The following actions should be considered if gas concentrations are detected:

1) Shut down the air intake (close dampers and/or de-energize fan supply as appropriate).
2) Shut down the process (to halt the release of flammable gas and in preparation for de-energizing the electrical power system).
3) De-energize non-explosion protected electrical power system or instruments.

Caution should be exercised when flammable gas sensors are installed inside ventilation air ducts or other turbulent flow applications. This equipment and sensors should be specifically designed, tested, and approved for low level flammable gas detection in turbulent air applications to ensure that the actions recommended above will function when flammable gases or vapours are present in the ventilation system.

Where pressurized rooms or houses are located in hazardous areas Zone 1 or 2, they are operated for electrical explosion protection according to IEC 60079-13 and/or IEC 61285. The Clean Air supply used for pressurization should be monitored with flammable gas detectors.

4.6 Specific considerations for open path detection

In Clause 4 so far, concentration units for gases and vapours have been:

a) percentage volume fraction (% v/v),
b) lower flammable limit, LFL (also known as lower explosive limit, LEL), which is expressed as a percentage volume fraction specific to a flammable substance, in air,

   NOTE For instance the LFL of methane is 4,4 % v/v in air (see IEC 60079-20-1).

c) percentage of the lower flammable limit, % LFL (% LEL), which is essentially an expression of reciprocal of the safety factor,
d) parts per million volume fraction (ppm), mainly used in connection with toxic gases and vapours, and flammable gases and vapours in low concentration.

These are the units usually employed in sensor and sampling equipment for oxygen deficiency and for flammable and toxic gases and vapours. At any one time, the sensors use a small, essentially homogeneous, sample which may be in a cell of low volume. Units of concentration are therefore appropriate.

The situation is different in open path equipment which essentially consists of a transmitter and receiver at the ends of an optical path of variable length from 1 metre to 200 metres. The sample is essentially all of the gas in the path between these devices,so it cannot be assumed to be homogeneous in concentration. There is no way of telling if there is a small cloud of high concentration, or a large cloud of low concentration, or more than one cloud. What is measured is the integral concentration over the path length (e.g. in LFL × m), as shown in Figure 1, or looked at another way, the average concentration (e.g. in % LFL(avg)) over the path length, as shown in Figure 2.

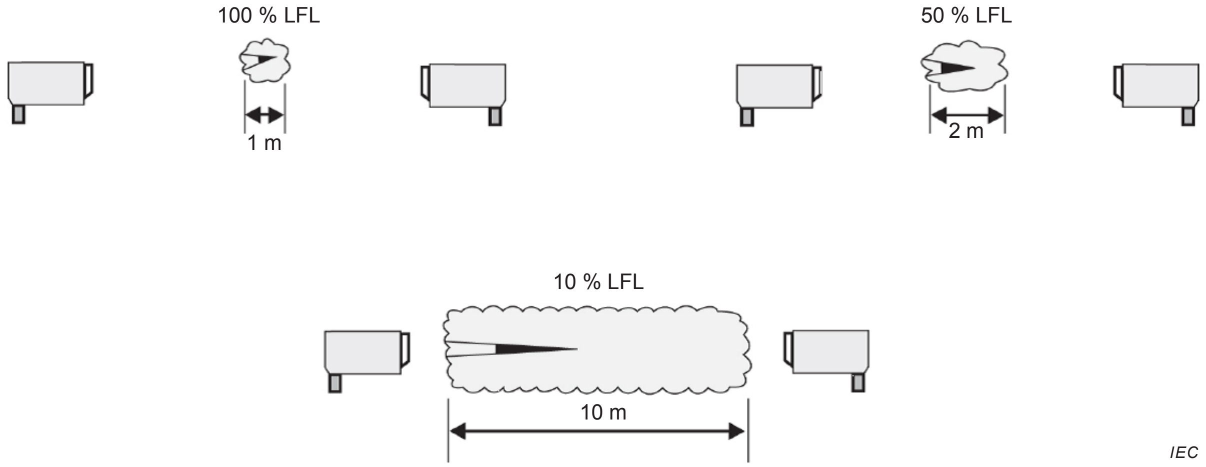

Figure 1 – Integral concentration over the path length

The three Open Path Monitors shown in Figure 1 detail how three gas clouds with different size and concentration would result in the same reading of 1 LFL × m.

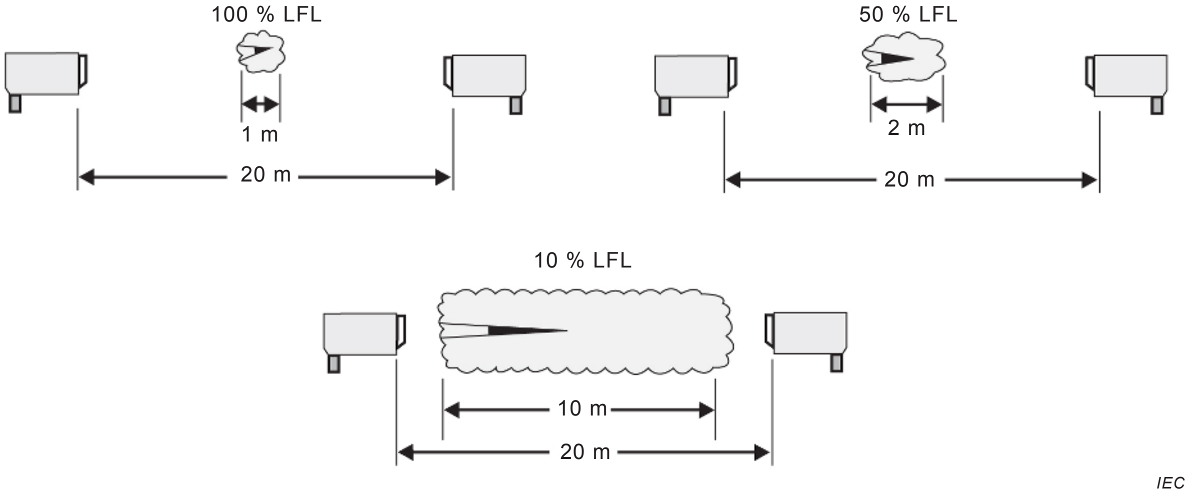

Figure 2 – Average concentration over the path length

The three Open Path Monitors shown in Figure 2 details how three gas clouds with different size and concentration would result in the same reading of 5 % LFL (Path Average Concentration).

5 Measuring principles

5.1 General

Clause 5 is an extract of Annex A to provide an overview of the most important aspects related to the measuring principles. For more detailed information please use Annex A instead of this clause. Titles and numbering of subclauses from 5.2 to 5.10.5 are identical with A.5.2 to A.10.5 of the annex.

It is useful for engineers and managers to know the measuring principles of gas sensors and/or gas sensing elements, when they decide the suitable gas detector for the intended application after talking with manufacturer or seller. However, the performance and function of the gas detector will not be decided only by the gas sensor or the gas sensing element applied to it. Therefore, it should be in mind that the selection of the gas detector should be done considering the total performance and function assisted by the peripheral hardware and software.

The measuring principles of various types of sensors are given below together with their advantages and typical applications and their limitations, interferences by other gases and poisoning (i.e. loss of sensitivity caused by other gases or vapours).

A summary of the most common detection principles is given in Table 2. These are explained in more detail in 5.2 to 5.10 (and in A.5.2 to A.10).

Table 2 – Overview of gas detection equipment with different measuring principles

	Catalytic sensor	**Thermal conductivity sensor**	**Infrared sensor**	**Semi-conductor sensor**	**Electro-chemical sensor**	**Flame ionisation detector**	**Flame temperature analyser**	**Photo ionisation 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 of flammable gases	≤ LFL	(0) to 100 % FS	0 to (100) % FS	≤ LFL	≤ LFL	≤ LFL	< LFL	< LFL	Not applicable
Typical measuring range open path	Not applicable	Not applicable	0 to 5 LFL × m	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Typical measuring ranges for oxygen	Not applicable	Not applicable	0 to (100) % FS (with special sensing elements)	Not applicable	0 to 25 % (0 to 100 %) FS	Not applicable	Not applicable	Not applicable	0 to 100 % FS
Flammable 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[e]	Flammable gases
Relative response time[a]	Depends on substance	Medium	(Low)	Depends on substance	Medium	Low	Low	Low	Low to medium
Interference of non-flammable gases[b]	No	CO_2; Freons	(Yes)	SO_2; NO_x H_2O	SO_2; NO_x	ClHCs[c]; Halon	(Halon)	Substance IP < X[e]	NO; NO_2
Poisoning[b]	Si; (Hal[d]); (H_2S); Pb	No	No	Si; Hal[d]; SO_2	(No)	(Si)	No	No	No
External gases required	No	No	No	No	No	Yes	Yes	No	(Yes/No)

[a] Qualitative comparison between principles. The values do not take into account time for aspirated sampling lines.

[b] Table gives common examples.

[c] Chlorinated hydrocarbons.

[d] Organic halogenated or inorganic halogen compounds.

[e] IP is the ionisation potential of the substance; X is the detector UV-lamp energy.

The statements in brackets are conditional and reference should be made to the corresponding subclause.

NOTE The term ‘Full Scale’ is denoted as “FS”.

Alternative detection technologies can be considered. However, the limitations of these alternative technologies should be assessed with respect to their ability or inability to determine the concentration of gas. Therefore, the hazard potential should be clearly understood in a safety system. As a consequence, alternative technologies which do not comply with gas measurement performance standards (e.g. IEC 60079-29-1 or IEC 60079_29_4) should only be considered as supplementary detection methods. For instance, ultrasonic detectors are available for detection of the presence of leaks particularly from high pressure sources. However, their characteristics are such that the earlier stages of a leak can give a stronger signal than a more developed leak with a higher flow rate. Therefore, such ultrasonic detectors should be regarded as a useful supplement to gas detectors, but in no way should be regarded as their replacement. Another example would be the use of infrared cameras which show location and rough extent rather than the gas measurement concentration.

5.2 Catalytic sensors

5.2.1 General

The principle of operation of catalytic sensors depends upon the oxidation of flammable gas on the surface of an electrically heated catalyst.

Catalytic sensors are capable of continuous operation for a few years, but will progressively drift and lose sensitivity due to ageing and traces of poisons. For this reason regular response checks and recalibration are required, the frequency depending on the severity of the application.

Sensor enclosures in most cases incorporate a permeable metal device to allow gas to reach the sensing element. It also ensures that, if the gas concentration is above LFL and may be ignited by the hot sensing elements, the atmosphere outside the enclosure is not ignited. This protection is also useful against dust or mechanical damage, as well as protection against excessive air velocities.

5.2.2 Common applications

Catalytic sensors are suitable for the detection of gas/air mixtures up to the lower flammable limit (LFL). They will detect in principle all flammable gases, but with variations in sensitivity.

The response time and sensitivity depend on the individual gas to be measured. The larger the molecular mass and molecular size of the gas, the longer will be the response time, and generally, the lower the sensitivity will be.

5.2.3 Limitations

A catalytic sensor needs sufficient oxygen for its operation. Insufficient oxygen concentration may be caused by high flammable gas concentrations well above the LFL or by inert gases.

WARNING – With concentrations above the lower flammable limit, a catalytic sensor may erroneously indicate that the concentration of flammable gas is below the LFL.

Therefore, equipment fully complying with IEC 60079-29-1 using catalytic sensors shall have a locking overrange indication to prevent erroneous readouts due to this. However, gas detection transmitters (e.g. 4 to 20 mA transmitters) and older equipment may not provide such protective features.

In case of gas detection transmitters not providing a locking function of the overrange signal the locking shall be provided by the central unit to comply with IEC 60079-29-1.

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.

Changes of pressure, temperature and humidity have only limited effect within the specified range. However, the lower the alarm level is set the greater will be the significance of variations in temperature and other environmental factors.

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

These sensors are not suitable for high sensitivity applications (e.g. ranges less than 10 % LFL).

5.2.4 Interferences

The response of a catalytic sensor may be lowered by inert gases like nitrogen or carbon dioxide or by condensation of water on the gas inlet e.g. in steam-laden atmospheres.

5.2.5 Poisoning

Catalytic sensors are susceptible to poisoning by traces of several substances. This leads to an inhibition which can be permanent or temporary depending on the contaminant.

Poisoning may result from exposure to substances as

- silicones (e.g. waterproofing, adhesives, release agents, special oils and greases, certain medical products, commercial cleaning agents);
- tetraethyl lead (e.g. leaded petrol, particularly aviation petrol ‘Avgas’);
- sulfur compounds;
- halogenated compounds;
- organo-phosphorus compounds (e.g. herbicides, insecticides, and phosphate esters in fireproof hydraulic fluids).

So-called "poison resistant" sensors can tolerate higher doses of these contaminants than traditional sensors before they suffer inhibition. In achieving this, their other properties may suffer (e.g. they may have a lower speed of response and reduced sensitivity).

Sensors may be protected against most poisons by the use of filters. However, filters should be used with great care. The advice in Annex A should be followed.

The manufacturer's guidance should be sought regarding which contaminants might poison the sensor and how the sensor can be protected.

5.3 Thermal conductivity sensors

5.3.1 General

The principle of operation of the thermal conductivity sensor depends upon the heat loss by conduction (and sometimes convection or mass transport as well) of an electrically heated resistance element. The sample is not consumed or altered by the sensor.

This type of sensor is suitable for monitoring those gases whose thermal conductivity in the desired detection range differs significantly from that of the reference environment (usually air).

5.3.2 Common applications

These sensors do not require oxygen for their operation and are capable of measuring concentrations up to 100 % v/v gas. Typically practical measuring ranges will be well above LFL.

These sensors are suitable for detecting an individual gas of high or low conductivity, relative to a nominated background gas (typically air). High conductivity gases like hydrogen, helium and neon have a good sensitivity in air, and the sensitivity for methane is usually acceptable.

5.3.3 Limitations

The technique is limited to applications where variations to the background gas are small compared with the response(s) of the gas or gases of interest in the required range.

The sensors will respond to all gases whether flammable or not.

The thermal conductivities of flammable 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 all the constituent gases in the mixture are known and stable. In the worst case, a mixture of high and low conductivity gases could cancel each other out and produce no response of the sensor.

5.3.4 Interferences

Each gas has its individual thermal conductivity and will influence the measurement.

A specific interference in many cases is water vapour since it can be highly variable, particularly in hot climates. Sample conditioning may be necessary.

5.3.5 Poisoning

There are no known poisoning effects.

5.4 Infrared sensors

5.4.1 General

The principle of operation of infrared sensors depends upon the absorption of energy of a beam of light by the molecules of the gas being detected.

Infrared sensors do not consume the sample, and they do not require oxygen for their operation. Sensor life is expected to be long.

This type of equipment allows the use of self-diagnostic measures which may extend operation periods between services. However, special consideration should be given to clogging of protective filters in the gas path since this will not normally be detected by self diagnostics.

5.4.2 Common applications

Infrared sensors are calibrated to detect a particular gas or, in some cases, a range of gases. Other gases will not be detected if their infrared absorption band is outside that of the sensor. Equipment incorporating such sensors should therefore be used only for the detection of gases for which they have been calibrated.

Typically practical measuring ranges will be from a few hundred parts per million up to 100 % v/v gas. The longer the optical path, the higher the sensitivity will be.

For the IR-measurement of oxygen TDLAS (Tunable Diode Laser Absorption Spectroscopy) devices are used for measuring ranges up to several %v/v or up to 100 v/v.

Typical applications of open path equipment include the lower alkanes, alkenes and alcohols. A typical measuring range is (0 to 5) LFL × m.

5.4.3 Limitations

Infrared detectors do not respond to hydrogen.

Pressure variations do not affect the zero gas reading, but sensitivity is normally proportional to partial pressure.

Some types of sensor relying on intermittent infrared beams or photoacoustic principles are susceptible to vibration.

Open-path designs may be sensitive to misalignment.

5.4.4 Interferences

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

Variations of water vapour concentration may affect the reading. However, point detection equipment that complies with the requirements of IEC 60079-29-1 will have minimal interference with water.

Solid and liquid contaminants may also cause interference or loss of sensitivity. It is important to prevent contamination of the optical components (e.g. windows and mirrors). When filters are used to keep optical components clean, regular maintenance is necessary to prevent blockage.

In the case of open path equipment, the potential effects of water vapour and interfering gases may be much higher. In addition, the equipment has to operate with dust, fog, rain or snow in the optical path, as well as with natural and artificial light. Open path equipment that complies with the requirements of IEC 60079-29-4 will have minimal interference effects on all of these effects.

5.4.5 Poisoning

There are no known poisoning effects.

5.5 Semiconductor sensors

5.5.1 General

The principle of operation of the semi-conductor sensor depends upon changes of electrical conductance that occur by chemisorption of the gas on the surface of the heated sensing element.

5.5.2 Common applications

Semiconductor sensors can be used for the detection of gases with measuring ranges from the parts per million level up to the LFL and even above. However, they have a non-linear response.

They are suitable for leak detection, even at very low concentrations, and for alarm-only equipment.

5.5.3 Limitations

Semiconductor sensors for flammable gases are generally non-specific, vulnerable to both humidity changes and interfering gases and may exhibit drift both of zero and span.

Preconditioning of new sensors or after long periods without power may be required, see Annex A.

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.

Variations of oxygen concentration, temperature, humidity or air speed may have a strong influence on the sensitivity.

5.5.4 Interferences

The measuring principle is generally not selective. However, improved sensing elements may have some selectivity. Non-flammable gases may induce a negative (e.g. NO_2) or a positive signal.

There may be a wide variation in sensitivity between sensors of the same type to particular gases and in addition, the relative sensitivities for these gases may vary significantly from one sensor to another.

5.5.5 Poisoning

The sensitivity can 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 sensors

5.6.1 General

The principle of operation of electrochemical sensors depends upon the change of the electrical parameters of electrodes in contact with an electrolyte when a specific gas is present. The change in the electrical parameters occurs due to a chemical reduction / oxidation (redox) reaction of the gas of interest at the surface of an electrode.

The sensors require recalibration at suitable intervals to correct for drifts in zero and sensitivity, and ultimately require replacement. Typical lifetimes under favourable conditions may exceed 2 years.

5.6.2 Common applications

Electrochemical sensors are not available for detecting most hydrocarbons They are suitable for measuring concentrations of hydrogen or carbon monoxide up to the LFL, and oxygen up to 25 % v/v. There are also sensors available for up to 100 % v/v oxygen.

Additionally, these sensors are commonly used for measuring concentrations of toxic gases down to low parts per million levels. Portable equipment for the detection of flammable gases, using other types of sensor described in this standard for their (0 to 100) % LFL ranges, frequently have such electrochemical toxic gas sensors and electrochemical oxygen sensors fitted in a multi-gas configuration.

5.6.3 Limitations

The response of an electrochemical sensor can be lowered by partial blockage e.g. by condensation of water.

Dependent on the sensor, oxygen may be required for the electrochemical reaction. In such cases dissolved oxygen in the electrolyte will last for short periods, but prolonged operation in oxygen-free situations is not possible.

Depending on the type of sensor and the gas to be measured (e.g. oxygen) the sensor can have a shortened life or a drop in response due to an overload of gas.

Low temperature or humidity can reduce the sensitivity and increase the response time of the sensor. Prolonged operation in very low humidity can dry out the electrolyte.

5.6.4 Interferences

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

With the exception of oxygen sensors, the sensitivity to interference can be in some cases higher than to the gas to be measured.

For some types of electrochemical sensors the sensitivity is proportional to atmospheric pressure. Other types of sensor are affected or damaged by pressure pulses.

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 flammable gases (see Annex A).

5.6.5 Poisoning

Electrochemical sensors can be affected by other gases resulting in a loss of sensitivity. Some oxygen sensors can lose their sensitivity due to high concentrations of CO_2.

5.7 Flame ionization detectors (FID)

5.7.1 General

The operating principle of the flame ionization detector depends upon the ionization (electrical charging) of organic compounds as they are burnt in a detector with an internal hydrogen flame.

5.7.2 Common applications

This type of sensor is used where high sensitivity, wide measuring range, small measuring uncertainty, poison resistance and fast response time are of main interest. The sensor is suitable for measuring ranges from the parts per million level up to the LFL and even above. Almost all organic compounds will give a signal.

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

5.7.3 Limitations

The principle of operation is not selective. If different gases are expected the sensor should be calibrated for that gas to which it is least sensitive. Relative responses are more calculable than for other measuring principles.

These sensors are not suitable for the detection of flammable inorganic gases. They will also detect some organic compounds which are not flammable.

External gases, hydrogen and (usually) synthetic air for its combustion are required. The signal is critically dependent on the stability of flow rates (see Annex A).

5.7.4 Interferences

Inert and rare gases, nitrogen oxides, halogens, nitrogen, oxygen, carbon dioxide, carbon tetrachloride, and water give no response.

Halogenated hydrocarbons reduce the response when the equipment is calibrated for measuring the total carbon content of the gas mixture.

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

5.7.5 Poisoning

Generally there is no poisoning effect, but if silicones or other substances that result in solid combustion products are present, they can result in a coating of the electrodes and insulation which will reduce the sensitivity and ultimately make the sensor inoperative.

5.8 Flame temperature analysers (FTA)

5.8.1 General

The operating principle of the flame temperature analyser detector depends upon the rise in temperature of a flame burning a constant flow of hydrogen (or some other gas) by flammable contaminants in the air sample supporting the flame’s combustion.

5.8.2 Common applications

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

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

5.8.3 Limitations

The principle of operation is not selective. At higher concentrations the response is not linear. The sensor is not recommended for measurement in parts per million ranges.

External gas(es) are 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 needs to be provided for the burner. The signal is critically dependent on the stability of flow rates, see Annex A.

5.8.4 Interferences

Halogenated hydrocarbons, such as halons at high concentrations, can decrease the signal by reduction of the flame temperature or even may extinguish the flame.

5.8.5 Poisoning

There is no known poisoning effect.

5.9 Photo ionisation detector (PID)

5.9.1 General

This detection principle is based on ionisation of gases by ultraviolet (uv) radiation of known wavelength.

The technique is not specific to flammable gases, and with the common ultraviolet lamps, it will not detect all flammable gases.

5.9.2 Common applications

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

This type of sensor is suitable for the measurement of gas concentrations from low parts per million range up to approximately 2000 ppm. Thus it is suitable for leak detection and for measuring gas concentrations from toxic levels to low percentages of LFL.

5.9.3 Limitations

The measuring principle is not selective for flammable gases but carbon monoxide, hydrogen, or methane in air can not be detected. Such sensors will detect all substances which have an ionisation potential (IP) lower than the energy of the UV-lamp and will not detect compounds having an IP higher than the lamp energy. Most sensors have a UV lamp with an energy of 10,6 eV (not suitable for low alkanes). The higher energy lamps tend to have reduced lifetimes.

5.9.4 Interferences

The response factor depends strongly on the ionization properties of the gas.

Humidity can induce a signal equivalent to several parts per million.

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

Condensed material, solid material, fingermarks, etc., on the lamp or cell windows can alter the ultraviolet intensity and hence the sensitivity.

5.9.5 Poisoning

Generally, there is no known poisoning effect.

The measurement of certain compounds like styrene or acrylates can lead to decomposition products being deposited on the UV lamp.

5.10 Paramagnetic oxygen detector

5.10.1 General

Oxygen is strongly paramagnetic (attracted to a magnetic field). Gases containing oxygen will tend to be drawn into a strong magnetic field with a force proportional to the oxygen concentration. The principle of operation is very specific because only NO and NO_2 are also paramagnetic but to a lesser extent.

5.10.2 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 100 % v/v oxygen.

Response times will depend on the particular design of the sensor.

5.10.3 Limitations

Dependent on the particular design, equipment may contain ignition sources, can be sensitive to shock and/or vibration or may require external gas(es).

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

5.10.4 Interference

Except for NO and NO_2, which give signals of around 50 % and 4 % respectively of the oxygen signal at equivalent concentrations, there are no significant interferences by other gases.

5.10.5 Poisoning

There is no known poisoning effect.

6 Selection of equipment

6.1 General

In Clause 6 and Clauses 8 and 9, there is a need for documentation of plant information, site information and decisions to be made. The documentation can be quite extensive, particularly for large fixed systems, and should be in an easily audited dossier. It is important that this is kept updated with changes to equipment, maintenance and calibration records. Annex C shows a typical check-list for many of the initial decisions.

NOTE 1 The performance standards IEC 60079-29-1 and IEC 60079-29-4 include certain minimum environmental tests. A summary of the environmental limits in these tests is found in Annex B. For equipment complying with IEC 60079-29-1 or IEC 60079-29-4, testing may have been performed beyond the minimum limits. In this case, details can be determined from the certification documents or test report.

In selecting flammable gas detection equipment, account should be taken of environmental factors and requirements relating to the situation where it is to be used and the intended application. Regard should be paid to the safety of any personnel who could be involved, particularly if vapours are present. For guidance, see Clause 4. Account should then be taken of any features of the equipment that may necessitate particular caution in its use and the interpretation of the output. Each of the various sensor types have inherent limitations, as described in Clause 5 or in more detail in Annex A.

NOTE 2 This standard is not intended to discourage the use of equipment 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 be such that the performance of the equipment is adequate and safe for the intended application.

For equipment for the detection of flammable gases, and related equipment, 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.

  NOTE 3 Assessment of the flammable gas detecting equipment against the performance requirements specified in IEC 60079-29-1 or IEC 60079-29-4 (as applicable) might provide a basis for judgement in appropriate circumstances. However, such performance testing might not necessarily include all functions of the equipment.

– Explosion protection test – To prevent the ignition of explosive atmospheres by the equipment itself.

  Conformance to explosion protection techniques in the IEC 60079 series of standards is required. This applies to all parts of the equipment, including sensors for other gases. Testing, certification and marking should comply with the appropriate national regulations. This is mandatory for all applications.

WARNING – Normal zoning and the appropriate explosion protection of equipment is not valid in oxygen enriched atmospheres for example, welding gas mixtures.

6.2 Selection criteria

6.2.1 General criteria

6.2.1.1 Criteria of selection of appropriate gas detection equipment

The following criteria are among those which should be considered when selecting appropriate gas detection equipment:

a) the gas(es) which the equipment is required to detect, the range of concentrations of each gas which may be encountered, and therefore the range and accuracy required;
b) the presence of potentially interfering gases;
c) the intended application of the equipment, for example area monitoring, personnel safety, leak detection or other purposes;
d) whether the equipment is required to be fixed, transportable or portable; For details, advantages, and restrictions of the three types, see also Clauses 8 and 9;
e) the method of obtaining the sample; diffusion, aspirated, or open path. For details and restrictions of all three types, see 6.2.3 and 8.2;
f) the classification of the intended Zone(s) of use in accordance with national regulations;
g) guidance for selection in relation to explosion protection as given in IEC 60079-14;
h) the environmental conditions that will be met in the area(s) of use, and comparison of this with the specifications of the proposed equipment;
i) the materials of the sensors and housings and their compatibility with the anticipated operating environment (corrosives, wind, rain, hosing, etc.). Copper components should

not be exposed where acetylene may be present because of the potential to form explosive acetylides;

j) any features of particular equipment that require caution to be taken in the use or interpretation of its output;

k) time dependency and interaction with safety devices and alarms (see 6.2.1.2);

l) calibration requirements including zero checks;

m) occupational health and safety requirements for installers, operators, calibration and other maintenance personnel and other persons likely to be in the protected area.

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

- the equipment 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.

6.2.1.2 Delay times

A gas detection and measurement system should be so designed that the delay time of the whole system is less than the maximum delay time allowable for the provided application. At least, the following factors should be taken into account:

a) potential release rate of flammable gas;

b) delay time of the sampling system;

c) response time of the sensor;

d) delay time of data transmission lines;

e) delay time of alarm devices and switching circuits;

f) time taken for executive action devices, for example shut-down valves, to operate;

g) time taken for any decisions and manual intervention;

h) degree of personnel training.

6.2.2 Gases to be detected by the equipment

The gas detection equipment is required to be sensitive to each of the gases that it is required to detect and also to be suitable for the range of gas concentrations that will be encountered. Reference should be made to the manufacturer's information to determine the suitability of particular detectors.

WARNING – Thermal conductivity, infrared, electrochemical, photoionisation and semi-conductor sensors may be sensitive to certain non-flammable gases, in addition to the range of flammable gases which they are intended to detect, and some of the techniques are insensitive to some flammable gases. For example semiconductor sensors may be sensitive to water vapour or to combustion products in addition to flammable gases. Advice should always be sought from the manufacturer concerning the effect of interfering gases on particular sensors.

It is not normally possible to determine the concentrations of individual flammable gases in a mixture of flammable gases using the types of equipment covered by this standard. In general, sensors of the types described in 5.2 to 5.9 respond to most or all of the flammable components of a mixture, without distinguishing between them.

Where a mixture of gases of known relative concentration is to be monitored, it is recommended that this mixture is used for calibration, if at all practicable. 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. Care should be taken to ensure that the sensors so calibrated will remain adequately sensitive to the other gases likely to be present. If this is not practicable, then an alternative approach is to select separate sensors, calibrated to the different gases likely to be present.

WARNING – The determination of the correct substance for the worst case calibration is not simple and requires much experience with the sensing element. Manufacturer's advice should be sought.

NOTE Worst case calibration is based on the gas with the lowest sensitivity with respect to the measuring range.

WARNING – Catalytic detectors have varying levels of sensitivity to different flammable gases. The ratio of response to different gases can change with time, particularly for methane or natural gas. If a range of gases is likely to be present in the area to be monitored, consult the manufacturer for recommendations on the most appropriate calibration gas. If methane is one of the gases to be detected, use a methane in air check gas or calibration gas (see 11.2).

Those parts of the gas detection equipment that are located in, or may be taken into, a hazardous area should have a certificate appropriate for that area and for the gases that may be encountered. The certificate should cover use of the equipment in the appropriate gas Group I, IIA, IIB or IIC, and temperature class, according to IEC 60079-0. Gas Group data on many individual gases are given in IEC 60079-20-1.

WARNING – Gas detection equipment of the types covered by this standard are not normally designed or certified for use in oxygen enriched or deficient atmospheres, and their use in such atmospheres should be avoided. For example particular care should be taken where oxy-acetylene welding operations are being carried out in an area protected by gas detection equipment; should an unlit oxygen enriched acetylene jet be accidentally directed at any of the gas sensors, an uncontrolled ignition could occur; oxygen enriched acetylene is a particularly dangerous gas mixture.

Some of the techniques (particularly catalytic) are not suitable for the detection of flammable gases in highly oxygen-deficient or inerted atmospheres. However, some techniques, notably infrared, are not dependent on oxygen concentrations.

In explosion protection applications where oxygen concentrations can significantly change, it is therefore necessary to have oxygen measurement. Typical measurements are made to:

- ensure the minimum oxygen concentration for correct functioning of equipment for the detection and measurement of flammable gases and vapours;
- ensure the maximum oxygen concentration permitted is not exceeded;
- monitor any increase in oxygen concentration which may increase the upper explosion limit and may decrease the energy required for ignition;
- protect personnel.

The lower and upper flammable limits of flammable gas in air will vary with temperature, pressure and oxygen concentration. Normal variations in these ambient conditions should not significantly affect the performance of the equipment. However, if larger variations of temperature, pressure or oxygen are expected, the manufacturer should be consulted (see the normal criteria in IEC 60079-29-1 or IEC 60079-29-4).

6.2.3 Application of fixed equipment

6.2.3.1 General

Fixed equipment and fixed systems 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 plants or mobile as in transport systems or mining production systems.

In general, fixed equipment consists of sensors, open path equipment or sampling points that are located in the hazardous area, and associated equipment that may be located either in the hazardous area or in a non-hazardous area such as a control room. All parts of the equipment or system are permanently installed.

According to the specific application, the suitability of the whole system has to be assessed, including the selection and the approximate number and placement of sensors, open path equipment or sampling points (see 8.3), the alarm levels and the response time. It may be appropriate to obtain advice from equipment manufacturers or a suitably trained person.

The fact that it is fixed permits the equipment to be energised ultimately from mains power. However the use of a battery back-up system will increase the availability of the equipment.

Fixed gas detection equipment may be designed to produce any or all of the following:

1) indication of gas concentration;
2) audible and/or visual alarms;
3) outputs to initiate actions such as process shutdown and automatic safeguard actions, for example process control, ventilation, elimination of ignition sources, etc.

Where item 3) is required, additional hardware may be necessary.

Each installation should be considered in its own right, in consultation with the manufacturer and safety authorities and in compliance with any mandatory local safety regulations.

There are four main classes of fixed equipment that are commonly used:

- single point sensors;
- remote sensors with centralised control equipment;
- sample systems with a centralised sensor package;
- open path systems.

The principal characteristics of each are listed in 6.2.3.2 to 6.2.3.5.

6.2.3.2 Point detection equipment (single point sensors)

This type of equipment has either a diffusion or an aspirated sensor and its signal processing control unit situated within the hazardous area. In this situation the sensor and control unit are usually combined, but may be supplied as separate items connected by a short cable. This type of sensor usually requires an external power supply (e.g.12 V to 28 V DC) and may have a standardised analogue output (e.g 4 mA to 20 mA) in a 2, 3, or 4-wire configuration, depending on the power requirements. If there is an alarm this will normally consist of voltage-free contacts, although there may be audible or visual outputs consistent with its hazardous area explosion protection.

The power supply and outputs are connected to undefined electrical equipment in the safe area, taking account of the explosion protection method (e.g. flameproof or via intrinsically safe barriers). Typically the design for compliance of this part of the system falls on the system designer and installer.

Application of calibration gases and adjustments of signal and any integral alarms has to be done entirely at the single point sensor.

6.2.3.3 Remote sensors with centralised control equipment

Remote sensors usually form part of a system having one or more individual sensors in the hazardous area separate from dedicated power supply and control equipment in a safe area.

Since all the equipment is designed as an integrated system, there is more design control by the manufacturer. Features such as diagnostics, central alarms and pre-designed explosion protection (e.g. dedicated intrinsically safe power supplies) are all possible options, simplifying the installation design.

Although application of calibration gases still has to be done at each remote sensor, some adjustments, particularly of alarms, and even the signal, may be done at the control equipment

NOTE This is the most suitable type for the majority of industrial applications, particularly if a rapid response is required, as it is totally dedicated to the one task.

6.2.3.4 Sample systems with centralised sensor package

This type of equipment usually consists of one to twenty or more sampling points in the hazardous area, connected to a sensor package (aspirated gas detection equipment including one or more sensors) by means of aspirated sample lines made of materials which are compatible with the sample (see 8.5).

Sample lines are usually selected in sequence for just enough time each for the sensor package to get a result and any automatic action (e.g. alarms, fault signals) to be initiated. Prepackaged sensor units with pump and automatic selection for this are available as standard items.

In estimating delays due to sampling, the time taken for analysing all currently-unsampled lines has to be taken into account in the worst case. Apart from the time for the sensor to obtain a sensible result on each fresh sample in turn, the transit time for a fresh sample to purge the line also has to be considered. Typical sample transit speeds in short lines are in the range 3 m/s to 10 m/s, depending on how critically the inside diameters of the sampling tubes have been chosen.

For sample lines more than a few tens of metres, it may be necessary to have a more advanced system. This may be a system where the next one or two lines to be sampled after the one currently being analysed, are drawn by a second pump. In this way fresh sample is already available at the sensor package when each new line is selected for analysis.

It is actually technically simpler, and will work to greater distances, to draw all lines, except for the one currently being analysed, by a larger bypass pump. In this last case, if the delays are acceptable, there is no practical limit to the length of sample line provided that the internal diameter of the tube is matched to the pump characteristics.

NOTE 1 Design of this type of equipment is a specialist task, but multipoint systems with sample lines as long as 7 km, and with delays around 95 minutes, have been successfully used for trend detection in coal mines.

This type of system may be more suitable than the previous two types where comparatively static process conditions apply and where conditions (environmental or accessibility) at the measuring point are unfavourable to a sensor; for instance there can be a much wider tolerance to temperature, vibration, chemicals etc.

The sensor package can contain sensors for more than one gas or vapour, operating in parallel. So apart from very infrequent verification of sample line integrity (e.g. using test gases), all routine calibration is performed at the sensor package only. In fact such features as automatic calibration may also be included.

Having a safe-area central sensor package also permits all of the electrical parts of the system to be located out of the hazardous area. In this case, apart from using flame arrestors where sampling lines pass from a hazardous to a non-hazardous area, specific hazardous area compliance may not be required. This permits those detection techniques in Clause 5 that cannot be easily explosion-protected, and in particular those requiring external gas supplies (e.g. FID and FTA), to be applied.

Multiple sampling systems also permit the use of other high sensitivity detection equipment which may be too expensive or cumbersome to be considered for use as point sensors.

Flame arrestors should be checked or certified to confirm that they are suitable for their application. They may consist of sintered metals, capillary holes, or other fine gaps, for operation. These devices may increase the response time, may be affected by corrosion, and may be prone to blockage by dust or condensation. This means specific examination and maintenance is required, but this can be mitigated by regularly maintained sample point filters and sensible sample line installation (see 8.5).

Where sampling systems can be used, they may be less expensive, and less maintenance intensive than the previous two types, particularly if both multiple sample points and multiple sensor types are needed.

NOTE 2 Equipment and systems of the kind described above are not deemed as a process control application which would then fall outside the scope of this standard.

6.2.3.5 Open path equipment

Open path equipment monitors a linear path through the atmosphere which may be as long as 200 m. There is a transmitter and a receiver at the ends of this path. The most common form is spectrophotometric open path equipment, which depends upon the absorption of energy of a beam of light, in the ultra violet, visible, or infrared parts of the spectrum. Most existing equipment operate within the infrared (IR) spectrum (see 5.4 and A.4).

In open path equipment, the transmitter and receiver may be combined as a transceiver, which then uses a reflector, typically a retroreflector to return the optical beam along a parallel path. For shorter distances, the beam may traverse parallel paths several times.

Typical applications are in monitoring the perimeters of oil platforms and other installations, process areas, the space under aircraft during maintenance, across stacks and across ventilation ducts, and in roof spaces.

The response of this type of equipment differs from the previous three (above) in that, instead of a concentration of gas or vapour, it measures the integral concentration along the path between transmitter and receiver (see 5.4).

There are three advantages in this technique; gas is monitored over an extended area, largely independent of wind direction, the signal is more representative of the magnitude of any release whether concentrated or diffuse, and because of the length of sample it is in effect extremely sensitive, and the equipment may be set at considerably lower alarm levels than typical point detectors.

Apart from its signal, the peculiarities of the technique are that it requires precise alignment. Special adjustment mountings are provided, and in many cases extra equipment (e.g. telescopes) are needed to achieve precise alignment of the optical axis. In turn there has to be an absence of vibration that could cause misalignment (particularly for long path lengths), which usually will require special footings and mounting structures. It requires, a clear line of sight that is not likely to be obscured by human activity or other moving objects, and it requires special means of calibration (see 8.11.1 and 8.11.2).

It is highly tolerant of natural and artificial light, dust, mist, fog, rain and snow (see A.4), but can be defeated by excessive fog or precipitation. Units complying with IEC 60079-29-4 will produce a beam blocked signal in such cases. Annex E provides some assistance in estimating likely atmospheric effects.

6.2.4 Application of transportable and portable equipment

6.2.4.1 General

Factors that are important in selecting portable or transportable equipment include its size, weight and robustness, its power supply requirements, the type of indication required, and the visibility or audibility of any alarms.

6.2.4.2 Transportable equipment

Transportable equipment should normally be selected for such purposes as monitoring temporary work areas ("hot" work) and areas where flammable liquids, vapours or gases may be transferred. Normally this is sensor based, but simple sampling equipment may be employed,

It is possible to have transportable open path equipment, but essentially all considerations for fixed devices will apply to it.

6.2.4.3 Portable equipment

Portable equipment should normally be selected for such purposes as leak detection, verification and monitoring of gas-free conditions, safety checks and similar applications.

In many cases small portable units can operate while attached to personnel’s clothing or equipment and become a personal alarm.

Portable equipment is frequently used in a simple diffusion mode. In such cases, where leak detection is involved or where the equipment is also used for the detection of gas in confined spaces beyond the normal reach of the user, either a static sample probe, or a hand or mechanically aspirated sample probe will be necessary.

Other portable equipment may have a continually-operating miniature electrical pump, normally drawing sample from the immediate vicinity of the equipment, but capable of drawing sample via a sample line or probe for the above purposes.

Sampling probes are associated with transportable and portable equipment, are usually short (in the order of 1 m) and rigid. However, they may be telescopic and may be connected to the equipment by a flexible tube.

Where portable equipment is, from time to time, likely to be exposed to gas concentrations greater than the lower flammable limit (LFL), care should be taken to select equipment suitable for that purpose.

Care should be taken to avoid condensation of water or sample vapour in the equipment and sampling line especially when cold equipment is transferred to an environment with a higher ambient temperature.

When equipment is moved from area to area it may experience sudden changes in temperature and pressure. This may give transient indications, for example from an electrochemical Oxygen sensor. Manufacturers’ advice on the size of such transient indications may be sought particularly to provide guidance when used in the ‘read and run’ mode (see 9.3.9).

For portable aspirated equipment, care has to be taken to ensure that the sample line is properly connected. Take care to connect the sample line to the pump inlet and not to the outlet.

Portable open path equipment consisting of a transceiver is available. Typically the technique uses the albedo of surfaces to reflect the infrared energy and may limit the open path length.

6.3 Miscellaneous factors affecting selection of equipment

6.3.1 Electromagnetic immunity

Some types of flammable gas detection equipment are susceptible to external radio frequency interference which causes malfunctions such as apparent errors in calibration, zero drift and false alarm signals. Where such problems are anticipated, suitable equipment, adequately protected against such interference, should be selected. (see IEC 61326-1)

6.3.2 Intended Zone(s) of use

Upon completion of area classification per IEC 60079-10-1 and IEC 60079-10-2, the gas detection equipment shall be properly selected with respect to the specific area classification.

7 Behaviour of gas releases

7.1 Nature of a release

7.1.1 General

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

7.1.2 Release rate of gas or vapour

The greater the release rate the larger the extent and/or rate of build-up of the flammable atmosphere.

The release rate itself depends on other parameters, namely:

a) geometry of the source of release.

   This is related to the physical characteristics of the source of release, for example 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 the 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 and subsequently by gas diffusion.

c) concentration.

   The concentration of flammable 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 flashpoint can be used as a guide.

An explosive atmosphere cannot exist if the flashpoint is significantly above the relevant maximum temperature of the flammable liquid. The lower the flashpoint, the greater the extent and/or rate of build-up of a flammable atmosphere will be.

Some liquids (for example certain halogenated hydrocarbons) do not possess a flashpoint 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 lower flammable limit should be compared with the relevant maximum liquid temperature.

Liquids have to be taken into account when their temperature is above (TF-*x*) K, where TF is the flashpoint and *x* is a safety margin. This safety margin is about 5 K for pure chemicals, but should be increased to 15 K for mixtures.

NOTE Under certain conditions, the mist of a flammable liquid can be released at a temperature below its flashpoint 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.

7.1.3 Flammable limits

The lower the LFL as a volume fraction of flammable gases or vapour in air, the greater will be the extent and/or rate of build-up of a flammable atmosphere. Given identical release rates, gases with lower LFL values will reach their ignition concentration more quickly than gases with high LFL values.

LFL and UFL both vary with temperature and pressure, but normal variations in these parameters do not appreciably affect the limits. A useful reference is IEC 60079-20-1.

NOTE Because LFL and UFL values are experimental, different countries specify different values for LFL and UFL, which have a legal standing. As two examples:

- NFPA 30 is a publication used within the USA,
- GESTIS is a publicly available database used within Germany.

7.1.4 Ventilation

An increased efficiency of ventilation usually reduces the extent and/or rate of build-up of a flammable atmosphere. Obstacles which impede the ventilation may increase the extent and/or rate of build-up of a flammable atmosphere. On the other hand, some obstacles, for example a bund, or walls or ceilings, may limit the extent and/or rate of build-up of a flammable atmosphere.

7.1.5 Relative density of the released gas or vapour

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

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

NOTE 1 For practical applications, a gas mixture which has a relative density below 0,8 is regarded as being lighter than air (e.g. methane, hydrogen or ammonia). If the relative density of a gas or vapour mixture is above 1,2, it is regarded as being heavier than air.

NOTE 2 Mixtures of high and low density gases with air will show less variation of density and, once mixed, they will not separate again; they can only become more diluted.

7.1.6 Temperature and/or pressure

If the gas or vapour prior to release is at a temperature and/or pressure significantly different from the ambient pressure and temperature, the absolute density of the release will be affected, and hence its behaviour, at least in the vicinity of the source.

A gas at high pressure escaping into the atmosphere may be strongly cooled as it expands adiabatically. Similarly an escape of compressed liquefied gas (e.g. LPG or ammonia) will be cooled to its boiling point, well below 0 °C.

Any thermally induced flow (e.g. convection currents from hot or cold surfaces or plant or equipment), particularly if adjacent to a source of release, may affect the propagation, and hence distribution, of a gas/air mixture.

7.1.7 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 will be modified as described in 7.2 and 7.3.

7.1.8 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 will be reduced, whilst downwind of the release it will be increased. This effect will be greater at high wind speeds. More complex air flow patterns will occur around buildings or other structures. In these cases, the wind direction may have 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 a 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.

7.2 Buildings and enclosures

7.2.1 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.

7.2.2 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.

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

7.2.3 Ventilated buildings and enclosures

7.2.3.1 General

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 considerably less than the LFL (lower flammable limit), it will tend to move with the normal air flow due to the small difference in density between the gas mixture and the uncontaminated air.

7.2.3.2 Natural ventilation

Natural ventilation is the flow of air into and out of a building or enclosure through any purposely 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, if the inside temperature 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 7.2. 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 IEC 60079-10-1.

7.2.3.3 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 (for example greater than 12 volume changes per hour).

NOTE 1 Mechanical ventilation is the technique used to control methane levels and provide breathable air in coal mines.

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.

NOTE 2 In case of very high gas concentrations (above LFL), or in the area above a flammable liquid with low flashpoint, an increased ventilation may lead to an increased volume of the explosive atmosphere.

In a well-designed ventilation 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 3 A device which generates smoke or mist to be used for checking the air flow visually can 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 on where the release might occur), then the alarm set point should be set as low as reasonably practical.

Some sensors use sintered materials as flame arrestors and the ability of an air/gas mixture to diffuse through the sinter to the sensing element can be adversely affected by very high air velocities that may occur in ducting arrangements. If this happens, additional shrouding of the sensor can help.

7.3 Environmental considerations

Environmental operational parameters should be included in the instruction manual of the intended equipment.

Where environmental conditions are beyond specified values, the manufacturer should be contacted to ensure that the equipment is suitable.

8 Design and installation of fixed gas detection systems

8.1 General

A fixed gas detection system should be capable of giving an early warning of both the presence and the general location of an accumulation of flammable gas, in order to initiate one or more of the following actions, either automatically or under manual control:

a) safe evacuation of premises;
b) appropriate fire-fighting and other emergency procedures;
c) removal of hazard;
d) shutdown of process or plant;
e) increasing ventilation.

The consequences to the safety of personnel, and the economic effects of potential damage following an undetected release should be of major concern. This should lead at the outset to consideration of integrity of the system, redundancy, integrity of power supplies, fail-safe operation, etc.

Therefore, it is of great importance that gas detection equipment is installed and used in such a way that only authorized personnel will have access to the functional controls of the equipment.

A major consideration is the selection of the quantity, and the locations, of sensors, sample points, or open path equipment. Practically this must be done by consideration of a wide range of factors including industry standards and regulatory authority requirements, the local environment and safety, and therefore usually requires a wide range of expertise.

8.2 Basic considerations for the installation of fixed systems

8.2.1 General

If the equipment or any auxiliary components are installed in a hazardous location (i.e. ‘classified’ or ‘zoned’ area), they should be suitable for the area in which they are installed and so marked.

Four main types of fixed systems are commonly used:

a) Systems consisting of individual point detection equipment (single point sensors), self-contained apart from their power supply, with either analogue outputs or voltage-free contacts, or both, for connection to alarm and control equipment by electrical cables.

b) Systems consisting of remote sensors connected to dedicated alarm and control equipment typically by electrical cables.

c) Sampling Systems, usually with multiple sampling points, feeding sample gas via tubes to a centralised sensor package with alarm and control equipment.

d) Open path equipment, sensing the gas in its optical path.

Systems of this type should, in general, be installed so as to be capable of continuously monitoring every part of the plant or other premises where flammable gases may accidentally accumulate. They should be capable of giving the earliest possible warning of an accidental release or accumulation of gas within practical limits of the system, for example as related to the number and location of sensors or line of sight open path.

8.2.2 Point detection equipment and remote sensors

Remote sensors and point sensors should be connected to their associated control and alarm equipment according to the national requirements for installation of electrical equipment. The sensors and any other parts of the system which are located in a hazardous area should incorporate an explosion protection technique covered by the IEC 60079 series of standards for the intended Zone of use. It should be noted that this might be somewhat easier to achieve for remote sensors. In this case the safe area control equipment is specifically designed to a part of IEC 60079 to be compatible with the remote sensors as regards power supply and outputs.

NOTE At excessively high and low temperatures the sensor can be operating outside the temperature range specified by the manufacturer and therefore might no longer comply with its explosion protection and/or performance certificate (IEC 60079 series).

8.2.3 Systems consisting of sampling equipment

These systems are used when comparatively static process conditions apply, and rapid response is less important; for instance monitoring for the early stages of progressive leakage. There are several technical advantages of this type of system:

- They can permit all of the electrical parts of the equipment to be located outside the hazardous area, with only tubes filters, etc., inside it and a suitable of flame arrester at the interface.
- They can be used where the desired measuring points are relatively inaccessible, or are under extreme environmental conditions.
- The central sensor package can use highly sensitive or bulky detection principles, and those requiring external gases; e.g. FID or FTA (see 5.7 and 5.8).
- The central sensor package can be readily equipped with automatic calibration and possibly some automatic maintenance.
- One sensor package can be used for sequential sampling from a large number of measuring points, and can contain sensors for more than one gas.

In this last case, the interval in time between two successive samples being taken at any one sample point should be sufficiently short that a potentially hazardous accumulation of flammable gas cannot occur during the interval. The length of any sample tube and the sampling flow rate should also be such that a potentially hazardous accumulation of flammable cannot occur during the time taken for a sample to pass from the sampling point to the sensor. For this reason, sample tubes should be as short as is reasonably practicable.

For systems with lines more than a few tens of metres long, the sample transit time from sampling point to sensor package is likely to be significant. In such cases the use of a second pump drawing on all lines not currently being sampled, or at least the next one or two lines due to be sampled, is recommended. The former requires simpler equipment but a larger pump.

8.2.4 Open path (line of sight) equipment

Such systems usually employ an infrared technique, where the transmitter and receiver are installed at opposite ends of a ‘line of sight’ path traversing an area. A retroreflector may be used on one side of the area so that the transmitter and receiver may be adjacent on the other side combined as a transceiver, and other configurations are possible.

Installation requires a clear line of sight which will not be interrupted, and an absence of vibration at each end. This usually requires substantial footings and mountings. Response is quick and to an extent independent of direction of air currents. For instance three or more such units located around the perimeter of an installation should pick up a release anywhere inside their perimeter, provided there is some air movement. Multiple units should be located in such a way as not to interfere with each other by reflection, particularly in fog or rain.

8.3 Location of detection points

8.3.1 General

The principal objective is that sensors, open path equipment and sampling points should be placed such that gas accumulations are detected before they create a significant hazard. Inappropriate location can completely nullify the effect and integrity of a gas detection system.

Furthermore, sensors, open path equipment and sampling points should be located in positions determined in consultation with those who have a knowledge of gas dispersion, those who have a knowledge of the process plant system and equipment involved, and safety and engineering personnel.

This determination should consider:

a) the combination of sources of release with propagation effects (see Clause 7);
b) whether the sources of release can be inside or outside confining structures, buildings etc.;
c) what can happen at access points such as doorways, windows, tunnels, trenches etc.;
d) local environmental conditions;
e) occupational health and safety;
f) access for maintenance including calibration and verification, and protection of the system against operational hazards of the plant.

The decisions reached on the locations of sensors and sampling points should be recorded in a safety dossier for the plant (refer also to 8.12).

NOTE Gas dispersion analysis can assist in determination of the appropriate location and numbers of sensors to be installed.

8.3.2 General site considerations

Where it is necessary only to detect the escape of gas from within a given area, then sensors or sample points may be placed at intervals around the perimeter of the site. Alternatively, a series of open path units may be used. 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.

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

Sensors or sample points should also be located in all areas where hazardous accumulations of gas may occur. Such areas might not necessarily be close to potential sources 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 might accumulate in overhead cavities.

If there is significant ambient air movement, or if 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 can 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.

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

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

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

8.3.3 Environmental conditions

8.3.3.1 General

Fixed equipment, or more particularly their sensors, may be exposed to a very wide range of environmental conditions for very long periods of time. Great care should be exercised in the selection and location of this equipment in relation to the likely environmental conditions applying in normal and abnormal use.

8.3.3.2 Adverse weather conditions

Sensors and open path equipment located on outdoor sites and open structures can be subjected to severe environmental conditions, and account should be taken of these conditions at all times. For example high winds may cause drift of the zero reading. High winds can even cause apparent transient loss of sensitivity during calibration due to dilution of the calibration gas being detected, if using the manufacturer’s normal calibration equipment. For high wind applications, the manufacturer should be consulted about these points.

Great care should be taken in the location of sensors and open path equipment in exposed sites, and adequate weather protection measures should be provided for the sensor. Steam, driving rain, snow, ice and dust, etc. can also adversely affect sensors. Certain materials, although otherwise suitable for sample lines or weather guards, can deteriorate from sunlight or other environmental conditions.

In open path equipment, there will be possible effects as above on the equipment itself, such as de-focussing due to water droplets on windows. However, the effects of dust, mist and mild rain or snow in the air of the open path itself will be minimal in equipment that complies with the requirements of IEC 60079-29-4.

Gas detection equipment located in buildings or enclosures is generally not exposed to adverse weather conditions.

In underground mines, consideration should be given to the effect of changing barometric pressure on gas releases.

8.3.3.3 Excessive ambient temperatures

All gas detection equipment should be mounted in areas which ensure compliance with the manufacturer's operating temperature specifications.

Where there are excessively high or low ambient temperatures, the detector might be operating outside the temperature range specified by the manufacturer, and detection errors and reduced sensor life may occur. In addition, at both excessively high and low temperatures, the equipment might no longer comply with its hazardous area certificate.

For example the electrolyte in many electrochemical sensors operating at temperatures much below –10 °C might be limited by freezing. Portable applications might get around this limitation by keeping the detector in a warm area when not in use.

In general, the positioning of gas detectors 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.

In tropical and subtropical applications, external sensors and equipment should be shielded from direct sunlight, as this can raise equipment temperatures above 65 °C even with ambient temperatures around 40 °C. The normal maximum for hazardous area certificates is 40 °C and the maximum for performance with IEC 60079-29-1 or with IEC 60079-29-4 is 55 °C, unless otherwise specified on the certificate.

Where temperatures at the measuring points are to be expected outside the specifications of sensors, sampling systems should be considered.

8.3.3.4 Vibration

Where vibration is expected, particularly for equipment mounted on machinery, care should be taken to ensure that it has been designed to withstand vibration, or that suitable vibration isolation mountings are provided. Open path equipment will require special anti-vibration mounting.

Where excessive vibration or buffeting at the measuring points is expected, sampling systems should be considered.

8.3.3.5 Use of sensors in corrosive atmospheres

Precautions should be taken to protect sensors from damage resulting from exposure to corrosive atmospheres (for example ammonia, acid mist, H_2S etc.). Particular care should be taken to protect wiring (and other components made of copper or brass) if ammonia can be present, as it can cause severe corrosion and electrical failures.

Sampling systems with filtering at the sample points against the corrosive atmosphere are a possible option.

8.3.3.6 Galvanic corrosion

Precautions should be taken to protect sensors from damage resulting from exposure to galvanic corrosion resulting from contact with other materials.

8.3.3.7 Mechanical protection

Sensors mounted in positions where they may be exposed to mechanical damage (e.g. from normal plant operations, or the use of mobile equipment such as fork lifts) should be adequately protected without impeding the free flow of air around them. If necessary, recommendations should be obtained from the manufacturer.

8.3.3.8 Electromagnetic immunity

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 adequately protected from the effects of electromagnetic interference.

NOTE It might be necessary to make reference to applicable national regulations regarding electromagnetic compatibility.

8.3.3.9 Hosing down

The practice of "hosing down" (use of high pressure hose) in a plant may cause severe degradation of gas sensors and contaminate sampling lines. It should, therefore, be avoided if possible. If it cannot be avoided, the sensors should be protected against this, without impeding the free flow of air around them. This can be a complex problem.

8.3.3.10 Airborne and other contaminants

Sensors should not be exposed to airborne contaminants which can adversely affect their operation.

For example, materials containing silicones or other known poisons should not be used where catalytic or semi-conductor sensors are installed.

Dusts, or wet, oily adhesive sprays and mists, or condensed droplets can block key items, such as the diffusion screens of sensors, or sample lines and their filters, causing loss of sensitivity or function. This is of even greater consequence if both wet and solid materials are present to form pastes. This contamination might require regular cleaning or similar maintenance. Sample extraction and special filtration may be required in extreme cases.

There are many examples where paint overspray, or deliberate painting has been responsible for failure of sensors. This requires some education of maintenance personnel.

Care should be taken to avoid water condensation on diffusion screens and in sample line(s). Where high humidity samples are involved, this can require heating of critical parts or deliberately removing condensed water in traps, coalescing filters etc.

There are particular problems where a vapour of interest can condense on (or the liquid can otherwise come into contact with) diffusion screens, filters, or sample lines or the windows of open path transmitters and receivers. This type of contamination will lead to incorrect and misleading signals until the last trace of contamination is removed. This can be extremely dangerous. If this type of contamination is possible, the only solution might be to heat the components that come into contact with the sample.

8.4 Access for calibration and maintenance

Measuring point equipment should be readily accessible to permit regular calibration, maintenance and electrical safety inspections. It shall be possible to access and fit all accessories or test equipment needed for these operations at the measuring point.

Where the sensor location makes this difficult (e.g. where it is high and over machinery) a system of lowering the sensing point on a pulley system or swinging arm to gain access may be practicable. Obviously, the cabling or sample tubing must be flexible or pivoted to permit this arrangement. The arrangement should preferably permit the original sensor orientation to be preserved for calibration.

If it is impossible to achieve regular direct access to the sensor then, as a minimum requirement, some form of remote gas calibration facility should be provided.

8.5 Additional considerations for sample lines

Sampling lines are usually permanently installed in fixed installations. Even if they are made of a flexible plastic material they will usually be less flexible and harder to install than cabling. Consideration should be made at the time of installation that they may need to be replaced in the future, for instance if they become badly contaminated or damaged. Joints need to be accessible.

Sample lines should be as short as possible since the response time is determined by the overall length.

Filters may be used to protect the equipment from dust and interfering or poisoning substances. Generally a particulate filter is needed at each sampling point so that its sampling line is kept clean internally. Additional devices are required for this purpose where mists may be sampled. Frequently additional filtration is provided at the sensor equipment.

Filters will increase the response time.

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

The flow rate through the sampling line should be monitored.

The material of the sample line(s) should be selected so as to avoid adsorption, absorption and chemical reactions with the gas being detected. In addition, care should be taken to avoid dilution of the sample by leakage or diffusion of dilutant air, or gas, into the sampling line or flammable gas out of the sampling line.

Where water condensation can occur it can block the sampling line. This is particularly likely to happen if the line runs through areas that can be cooler than the sampling point (e.g. air conditioned areas in hot humid climates). If going through cool areas the sample line should if possible run slightly downhill from the sample point towards the sensor. Water traps might be needed at any low spots along the sample line length. Care shall be taken with these, since long or high-speed sampling lines may operate at a high partial vacuum. This means that automatic emptying can only be done using manometric ‘legs’ of adequate length, or some sort of blow-back system with non-return valves. Alternatively, the line may be heated, as explained in the next paragraph.

Consideration should also be given to the effects of condensation of the vapours of high flash point liquids in sampling systems. This will reduce the concentration in the sample and hence the reading. Subsequent samples with lower concentrations of the vapour will permit it to re evaporate, giving incorrectly high readings. To minimize this effect, heating of the sampling line might be necessary. In hazardous areas if this heating system is electrical it shall comply with the relevant regulations and standards. Steam or hot water trace heating may be an option.

8.6 Additional considerations for open path equipment

Open path equipment has optical windows and reflectors exposed to the ambient conditions. Partial protection may be given by integral short tubes or overhead covers.

Condensing mists and dew might be a problem unless the optical parts have some sort of heater to raise them above the dew point.

Open path equipment will not be proof against sunlight, reflected sunlight (particularly off water) or high intensity natural light coming into their receivers at narrow angles from the optical axis. Sighting of equipment shall consider the direction of sunrise and sunset at different times of the year, vehicle paths at night and the possible use of screening or sighting relative to buildings.

Because open paths can be rendered inoperable in dense fogs or intense rain or snow, or, in the case of perimeter protection, by very still air, it is advisable to combine a system of open path equipment with sensors or sample systems.

8.7 Summary of considerations for the location of measuring points and open paths

The rationale for the selection of location of measuring points and open paths should be formally recorded in the dossier (refer to 8.2 and 8.12).

NOTE Reference can be made to IEC 60079-10-1 for further information on area classification and gas dispersion.

Points a) to p) are a basic check list of factors which should be taken into account, in no particular order of priority, in determining suitable measuring point or open path locations. These include, but are not limited to, the following:

a) indoor or outdoor site;
b) potential sources of emission – the location and nature of the potential vapour/gas sources (for example density, pressure, amount, source temperature, and distance) shall be assessed;
c) chemical and physical data of the potential gases/vapours present;
d) liquids with low volatility need sensors near the potential source of release (and low alarm or action points);
e) nature and concentrations of gas releases likely (for example high pressure jet, slow leaks, spillage of liquids);
f) presence of cavities and jets;
g) topography of the site;
h) air movements:
    1) indoors: natural ventilation, mechanical ventilation, convection,
    2) outdoors: wind speed and direction;
i) temperature effects;
j) environmental conditions of the plant;
k) location and number of personnel in the area;
l) location of potential sources of ignition;
m) structural arrangements (such as walls, troughs or partitions) which could allow vapour/gas to accumulate;
n) prescribed locations;

o) detectors should be installed so that they are not vulnerable to mechanical or water damage from normal operations; and

p) locations should be such that sensors can be readily maintained and calibrated.

8.8 Installation of measuring point and open path equipment

For the reliable operation of a fixed gas detection system each sensor, sampling point or component of open path equipment should be placed in a suitable location according to its individual application, and as decided in 8.7.

However, inspection and maintenance, including recalibration with gas, or replacement of sample point filters, shall be carried out periodically by trained personnel. Therefore, access for such operations also needs to be considered in detail during installation.

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

In many cases, the orientation of the equipment may be specified by the manufacturer.

Adequate drainage and/or heating should be incorporated into the system design to minimize moisture and condensation in the equipment, detector head and interconnecting cable/conduit system, or sampling tube.

Any potential flammable gases introduced into sampling systems should be vented in a safe manner.

Lubricate all threaded connections, but ascertain that the lubricant contains no substance (for example silicone) that might be deleterious to the sensors.

Sensors shall be connected to their respective control unit, as specified by the manufacturer (observing maximum loop resistance, minimum wire size, isolation recommendations, etc). The interconnecting system, including wiring and conduit system, between the sensing equipment and control unit should be suitable and approved for the purpose, area classification, and mechanical protection.

If the user is not able to address these points the work should be carried out by the manufacturer or other competent person.

8.9 Integrity and safety of fixed systems

8.9.1 General

If the gas detector system or channels of a system fail or are removed from service, so that areas of the plant cannot be monitored sufficiently, additional measures may be required to preserve safety. Planning for such eventualities should happen before installation.

It is similarly essential that safety is maintained when the gas detection system, or a part of it, becomes inoperative during routine calibration.

Additional measures to preserve safety may include:

a) signalling of gas detection equipment faults;

b) use of portable or transportable gas detection equipment;

c) increased ventilation;

d) elimination of ignition sources;

e) interruption of supply of flammable gases or liquids;

f) switching-off of plants or parts of them; and

g) duplication of the most essential sensors.

8.9.2 Redundancy in fixed systems

In general, a fixed system should be so installed that failure of individual elements of the system, or their temporary removal for maintenance, does not compromise the safety of the personnel and premises being protected. Duplication or triplication of remote sensors and control equipment is recommended in all areas where continuous monitoring is absolutely essential. To obtain maximum safety integrity, this redundancy can be made more effective by using sensors of different manufacture or different detection principles to eliminate common failure modes. Use of an open path system in conjunction with point detectors can for instance be a significant safety feature. Devices that operate 'fail safe' should be used wherever possible.

8.9.3 Protection against loss of main power supply

Protection against loss of the main power supply should include:

a) main power supply.

The main power supply should be designed so that the unrestricted operation of gas detection equipment and alarm functions are guaranteed.

Breakdown or fault of main energy supply should be detectable. Safety of the monitored area shall be preserved by appropriate measures.

The main power supply should have a separate circuit with specially marked fuse used only for the gas detection equipment.

b) emergency power supply.

If an emergency power supply is required to maintain the function of the gas detection equipment, it should do so until the normal state of supply is restarted or the monitored area no longer requires monitoring. Any peripheral external power supply shall be suitable for the area for which it is to be used (both for environmental considerations and for the area classification).

Breakdown of emergency power supply should be indicated by an alarm signal.

It is strongly recommended that for indication of power and/or equipment failure, contacts are used which are closed in the non activated state (fail-safe).

8.10 Timing of installation during construction operations

Gas detection equipment should be installed as late as possible in any programme of construction operations (i.e. the construction of a new plant, refitting or maintenance) but before the presence of gas or vapours in the system, so as to avoid damage to sensors, sample lines, or other parts resulting in particular from such activities as welding and painting.

If already installed, sensors should be protected with an air-tight seal to avoid contamination during construction work, and should be clearly marked as being non-operational.

8.11 Commissioning

8.11.1 Inspection

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, and that, where appropriate, the methods, materials and components used are in accordance with IEC 60079-0.

NOTE Guidance for installations in hazardous areas are found in IEC 60079-14.

Among the items to be inspected are the following:

a) confirm electrical connections are properly tightened;
b) check for sample-line leaks and proper flow;
c) check for clogged or dirty flame-arresting systems;
d) check the battery voltage and/or battery condition and make any required adjustments or battery replacements (according to the instruction manual);
e) perform a test of the failure (malfunction) circuit(s).

A check should be made at this time to confirm that a full dossier of operating instructions, plans and records for the complete system have been supplied. This should have details of all measuring points and open paths (refer to 8.3). The instructions should include details on use, testing, calibration and operation, and should include all manufacturers' instructions (refer to 8.12).

8.11.2 Initial gas calibration

After installation on site each sensor should be calibrated according to the manufacturer's instructions, unless it carries currently valid factory calibration certification for the gas of interest. Calibration should only be carried out by a suitably trained and competent person.

For sensor systems, calibration of installed gas detection equipment is normally carried out by application of a zeroing gas, or by verifying that the area is gas free, and the signal of the equipment is then zeroed. Then a span gas is applied and the sensitivity of the equipment adjusted to an appropriate value (generally as per 11.8.1, 11.8.2.4 and 11.8.2.5).

This procedure has to be considerably modified for open path equipment. In order to perform a true zero check, the entire path length needs to be verified gas free. Typically this requires a portable gas detector, which in the case of the longer paths needs to be of extremely high sensitivity, such as PID (see 5.9). In order to perform a span check or adjustment, a sealed sample of calibration gas in a cell with transparent ends has to be introduced into the beam path.

NOTE Use of a pre-calibrated optical filter, while suitable for functional checking, is not recommended for calibration.

After the initial gas calibration, fixed systems should automatically revert to the monitoring mode after a pre-determined interval without further adjustment. Alternatively, during calibration, the equipment should produce a special (e.g. maintenance) signal to prevent the output from being mistaken for a normal measurement.

Where a number of gases are likely to be present, reference should be made to the additional precautions described in 4.3.2.2 and 6.2.2.

To ensure correct operation, it is essential to carry out both inspection and recalibration periodically.

8.11.3 Adjustment of alarm set points

In the case of detection equipment only indicating up to the lower flammable limit, the alarm set point (or the lowest set point, where there are two or more) should be as low as possible commensurate with the need to avoid false alarm signals. The alarm set points shall be documented in the system dossier (refer to 8.12).

This might need frequent review during the early stages of operation of a new plant or gas detection system.

Adjustments should be carried out in accordance with the manufacturer's instructions.

8.12 Operating instructions, plans and records

Instructions on the use, testing and operation of fixed gas detection systems should be made available and placed in the system dossier.

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

It is extremely important that the equipment manufacturer's installation manual be read thoroughly, and the instructions followed completely. Again, a copy of this should be in the dossier.

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

Routine tests of the flammable gas detection system are an extremely important factor affecting the reliability of the individual units. Optimum system performance and reliable operation will only be achieved through a defined program of comprehensive tests.

All types of gas detectors will require periodic recalibration using appropriate calibration gases. Where sensors are used that have definite service lives and/or susceptibility to poisoning (e.g. catalytic, electrochemical, semi-conductor) regular recalibration, or at least functional checks, will be required. The required frequency may be specified by regulations of the responsible authorities. In most cases advice or recommendations can be obtained from the manufacturer. Ultimately it will depend on the severity of the application, and is best determined by starting a process of regular frequent checks and logging the results (amount of adjustment required etc) in the dossier. Periodic review will enable the most desirable interval between calibrations and/or functional checks to be found. If different intervals are defined, the shortest time period should be taken. The detection system should be frequently re-inspected by a competent person. The inspection should be in accordance with the instructions of the manufacturer and the specific requirements of the application. A visual inspection of all units of the gas detection system should be carried out and the test and alarm 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.

Where sampling systems are used, the sample lines should be checked for contamination and inwards leakage. An easy way to do the latter is to apply calibration gas via a bladder, or otherwise at atmospheric pressure, at the sample point (DO NOT USE PRESSURE) and see if a similar result is obtained as in the normal calibration.

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 in the dossier.

9 Use of portable and transportable flammable gas detection equipment

9.1 General

Each time a portable or transportable gas detection equipment is used, its user is also essentially carrying out many of the same important functions as described in Clause 8 for fixed installations. However, the user may not have all of the skills needed.

There are particular additional problems where users hire or borrow portable or transportable equipment of this type. Relevant parts of Clause 6 may not have been properly applied. The maintenance and calibration history may not be known and the user may be unfamiliar with the particular equipment.

Personnel responsible for users of portable and transportable equipment essentially have two options. These are:

a) To give personnel required to use portable or transportable gas detection equipment proper training in its use, which would include Clauses 4, 5, 9, 10, and Annex A, and to train on and provide ready access to the operating instructions of the particular equipment.
b) To adopt the minimalist approach described as “read and run” in 9.3.9, following basic training on the particular equipment and on any personal safety precautions relating to the particular application and any toxicity. Checking, calibration, etc. should then be done by others.

The various types of portable and transportable gas detection equipment may be used in a variety of ways according to their particular design and specification. An important point is that they should never be used without additional precautions and training where a significant quantity of gas is actually known to be present, particularly if option (b) is taken. The necessary steps to remove the gas should have been taken already.

NOTE There are certain applications where gas is always unavoidably present, such as in coal mines. Special training is required for such applications.

Small, hand-held equipment may be used for leak-detection or spot checks, while larger portables, some with visual and/or audible alarms, may be used in multi-role mode so as to include leak detection, spot checking and local area monitoring functions, according to the particular needs of the user.

Transportable equipment is intended for use for temporary area monitoring in locations where there is a probability of generating potentially flammable gas or vapour mixtures, for example during the loading or unloading of fuel or chemical tankers or where temporary "hot work" (in connection with maintenance activities) may be in progress in classified hazardous areas under the authority of a gas-free certificate. Transportable equipment is not intended to be hand carried for long periods of time, but is intended to be in place for periods of hours or more.

Due to their very nature, portable and transportable equipment may encounter a wide range of climatic, handling or more generally environmental conditions. Thus, the user should pay particular attention to the actual conditions imposed on equipment and assess that it is designed or protected so as to meet these conditions. This applies not only to its use, but also when it is not being used, for instance mechanical damage, vibration when it is being transported, or excessive temperatures experienced on the back shelf of a parked car in the sun.

Routine testing of the flammable gas detection equipment is an important factor affecting reliability. Optimum system performance and reliable operation will only be achieved through a program of tests. The frequency of the tests will depend on the effects of possible poisoning and aging on the type of sensor used (see Annex A) but otherwise can only be determined by experience of the particular application.

9.2 Initial and periodic check procedures for portable and transportable instrumentation

9.2.1 General

Due to the fact that portable and transportable instruments are generally not used continuously, initial and periodic check procedures are of the utmost importance to ensure that the equipment is in a proper state of operation. A distinction is drawn between functional checks where no adjustment is made by the user, and recalibration where adjustment is made when necessary, although they use similar equipment. This is more a case of responsibility. The manufacturer's instructions for these checks should be precisely followed.

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

9.2.2 Inspection and functional checks

Inspection and functional checks are intended to verify that the equipment is in a working state. It is recommended that they are done by personnel actually operating the equipment, and is performed before each day of use, particularly if the equipment has catalytic, electrochemical, or semiconductor sensors and is being used under arduous conditions.

NOTE 1 The instruction manual of portable equipment complying with IEC 60079-29-1:2007 is required in 4.4 of that standard to provide a method for performing a functional check with gas before each day of use.

In critical cases where a permit to work is given as the result of a gas test, it is recommended that a functional check is performed afterwards, and that the result of both the gas test and the functional check are logged.

A simple sequence of inspections may include the following:

1) checking the battery voltage and/or battery condition;
2) allowing adequate warm-up time;
3) checking for sample-line leaks and proper flow in aspirated equipment;
4) checking that a zero reading is displayed when operated in clean air (see note below);
5) performing a functional check.

Items (4) and (5) may be performed as follows:

Place the equipment or that part of the equipment that includes the sensor(s), or the sampling line, in an atmosphere free of flammable gas, aspirate a large enough sample to purge the lines (applicable only to equipment with sampling lines). If a significant deviation from zero is observed (but see Note 2), the equipment should be recalibrated (see 9.2.3). Some instruments have an automatic zero check which will do this adjustment.

NOTE 2 Although there should be no measurable amount of flammable gases in clean air, and therefore a flammable gas sensor should read zero, this is not necessarily true for other sensors that may be incorporated in the same instrument: Oxygen sensors should read 20,8 or 20,9 % v/v under these conditions. There are approximately 380 parts per million of carbon dioxide (more in heavily built-up areas) which should give appropriate readings (e.g. 0,03 or 0,04 % v/v CO_2). Also in built up areas, there may be detectable amounts of CO.

The sensitivity of the equipment should be checked using the field calibration kit recommended by the manufacturer and performed with a known gas mixture which will give a response from all the sensors present. The user should know or should be instructed what reading(s) should be obtained. If the test results are not within ±10 % of the anticipated result, the equipment should be subjected to further investigation by appropriately qualified personnel.

For catalytic sensors the mixture should contain at least 10 % by volume of oxygen.

NOTE 3 Very reactive gases like fluorine, hydrogen chloride or ozone are not suitable to be used within calibration gas mixtures for functional checks. In such cases, users would do well to consult with the manufacturer as to whether an alternative species with defined cross sensitivity responses may be used.

For alarm-only equipment, a test gas concentration should be applied which is equal to 5 % LFL above the highest alarm set point of the equipment. All alarms should actuate during this test. If equipment fails this procedure, and suggested corrective action does not solve the problem, the equipment should be recalibrated (see 9.2.3).

9.2.3 Routine tests and recalibration

Portable and transportable equipment should be regularly recalibrated in a suitable workshop by a competent person. Any equipment that is used infrequently should, nevertheless, be regularly inspected, and calibrated, so that it may be available for immediate use when required. This should be done in accordance with the manufacturer's instructions and typically may include:

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 arrestor (11.4.2) or breathing devices;
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) testing the alarm circuits;
i) recalibrating by adjusting to a zero reading when operated in clean air and the correct value when a known calibration gas is applied. This may be done as follows:

Place the equipment or that part of the equipment that includes the sensor(s), or the sampling line, in an atmosphere free of flammable gas, aspirate a large enough sample to purge the lines (applicable only to equipment with sampling lines). If a deviation from zero is observed it should be recorded and then adjusted to zero. Some equipment has an automatic zero check which will do this adjustment.

The sensitivity of the equipment should be checked using the field calibration kit recommended by the manufacturer and performed with a known gas mixture which will give a response from all the sensors present. The concentration of flammable gas should preferably be chosen to give a reading between 25 % and 75 % of the full scale. This reading may also be specified by the manufacturer. If a deviation from the correct value is observed it should be recorded and then adjusted correctly. Some equipment has an automatic sensitivity adjustment, and will only do this correctly with the specified gas.

For catalytic sensors the mixture should contain at least 10 % by volume of oxygen. In some modern multi-gas equipment the gas specified by the manufacturer may have a known oxygen concentration above this value, and known concentrations of some toxic gases. This is used to simultaneously recalibrate all its sensors.

NOTE Very reactive gases like fluorine, hydrogen chloride or ozone are not suitable to be used within calibration gas mixtures for functional checks. In such cases, users can consult with the manufacturer as to whether an alternative species with defined cross sensitivity responses may be used.

For alarm-only equipment, a test gas concentration should be applied which is equal to 5 % LFL above the highest alarm set point of the equipment. All alarms should actuate during this test. If not, the equipment should be recalibrated.

The records of these checks may be used for long-term analysis for determining an optimum frequency of recalibration.

9.2.4 Maintenance and recalibration

Maintenance procedures should be undertaken only by qualified personnel trained in the operation, maintenance, and repair of flammable gas detection equipment. 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 equipment to the manufacturer or other qualified outlet of repair. In the case of explosion-protected equipment, the manufacturer should be consulted with regard to replacement parts.

For portable and transportable gas detection equipment, 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:

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

The results of maintenance and recalibration should be recorded in the dossier.

9.3 Guidance on the use of portable and transportable equipment

9.3.1 Electrical safety in hazardous atmospheres

Portable and transportable equipment should have a type of protection appropriate for the location in which it is intended to be used. During use, portable and transportable equipment should not be transferred from a Zone of lower risk to a Zone of higher risk unless it is suitably protected for the higher risk. Additionally, the equipment Group and the temperature class should be appropriate for all gases and vapours in which the equipment may be used (see IEC 60079-20-1).

9.3.2 Safety of personnel

When about to work in a hazardous area it is necessary to specifically check on the potential toxicity of the atmosphere and the likely origin of any oxygen deficiency with the plant Safety Officer, Industrial Hygienist, or equivalent, particularly if confined spaces are involved. (see also Clause 4).

Oxygen deficiency may be due to the presence of toxic amounts of some other substance.

Some flammable gases (for example ammonia, hydrogen sulfide) and almost all vapours are also toxic and even lethal at very low percentages of LFL.

If the flammable gas equipment is also equipped with high sensitivity sensors for specific toxic gases, it should be realized that it will usually not detect other toxic materials.

Gas detecting equipment on its own may not be sufficient protection if toxic substances are likely to be present. In some instances an appropriate respirator and /or other devices may be needed as well.

Switch on the equipment, allow it to warm up as necessary, and perform any clean air checks (see 9.2.2) in a safe area but as close as practicable to the ambient conditions in the area to be monitored.

When entering the potentially hazardous area the user should frequently observe the readings on the equipment. The user could be entering an already dangerous situation and may need all the warning they can get.

9.3.3 Spot tests and sampling

The equipment will only give a reading for the location where the reading is being taken, or the location of the end of a sampling line, if used. A hazardous atmosphere may be building up a few metres from the sampling point. Therefore many gas tests shall be done all around the intended area of work to ensure that no pockets of hazardous gas or vapours are present in the work area.

If vapours are likely to be present, some of the tests should be done a few millimetres from the floor, including all nearby low spots, using an extension probe or sample line if necessary. These tests might detect a small problem (e.g. from a minor liquid leak) at an early stage.

Only sample lines recommended by the manufacturer should be used (see notes on adsorption and chemical reactions in 8.4).

Similarly if light gases (e.g hydrogen, methane, ammonia) are likely to be present, some tests should be done near the ceiling or at least as high as practicable.

The readings are only valid for the time they are taken. Circumstances change. Frequent readings are recommended, particularly if liquids could be involved and the temperature is rising.

If there is any likelihood of sample probes coming into contact with mains-operated equipment, then the sample probes should be made of non-conducting material, and probes and lines should be kept dry.

9.3.4 Sampling above liquids

When sampling vapour above a liquid, care should be taken to avoid the sample line or sensor from coming into contact with the liquid, since this may block the gas entry to the equipment, could damage the sampling system or sensor, and cause erroneous readings. Use a hydrophobic filter or equivalent where there is danger of drawing water into the detector. A probe with side entry and a solid tip can help to avoid drawing liquid in.

Once an equipment or its accessories have been contaminated by liquid it shall be regarded as unusable until the contamination has been completely removed.

9.3.5 Avoidance of condensation

When taking a portable equipment from a cool environment to a warm environment, it is important that time is taken to allow the equipment temperature to rise sufficiently to avoid vapour condensation which may cause contamination and/or 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.

9.3.6 Poisoning of sensors

If the portable equipment is of the multi-gas type containing sensors for the detection of toxic gases at low concentrations then calibration with some toxic gases, typically hydrogen sulfide, ammonia and chlorine, may cause inhibition of some flammable gas-sensing elements, particularly catalytic devices. Only use the test gases and calibration procedure stipulated by the manufacturer. It is recommended that if in normal use an alarm is given for any of these gases, the flammable gas sensor should be checked before it is further used.

If there is a chance of sensor ‘poisons’ (such as silicones, leaded petrol, acids, etc) being in the environment, the sensitivity of a catalytic, electrochemical or semiconductor equipment shall be checked at frequent intervals (see 9.2.2).

9.3.7 Changes of temperature

When temperatures are rising, and vapours of liquids could be involved, gas testing should be frequent in view of the fact that vapour concentration could possibly double for each 10 K rise in temperature.

9.3.8 Accidental damage

If a portable or transportable gas detection equipment is dropped or otherwise damaged, it could have affected its explosion protection and/or performance. It should immediately be taken out of service for inspection, for any necessary repairs and for re-calibration, before re-use.

9.3.9 Minimalist operation, the “Read and run” concept

The safety margins are increased if small changes in readings are observed, rather than only relying on alarms that are always set significantly above zero.

Without extensive training, the user should not be put in a position to be gas testing where significant amounts of gases or vapours are actually present or expected.

Accuracy is not important as long as the equipment will respond to a functional check: The user is not to be expected to make a measurement, the intention is just to detect gas.

The user working in a hazardous location may not be fully familiar with gas surveying or the toxic nature of the environment. In such cases the advice to the user is to employ the ‘Read and run’ concept with consideration of local permitting practices.

Under this concept the basic operations are as follows:

a) Observe the readings in clean air, as close as possible to the conditions that are going to be encountered at the point where the sampling will take place, particularly with regard to atmospheric temperature and humidity.

   NOTE Altitude is also important; a change of 100 m in altitude can change an oxygen reading.

b) Adjust the equipment to its proper clean air readings. Or, if this is not allowed or not practicable, write down the clean air readings obtained.
c) When entering the area where the tests are required, if there is any indicated change from the clean air reading, this is a ‘positive reading’.
d) If you get such a positive reading **GET OUT**, that is ‘**Read and run**’.
e) Then inform the responsible person, who may then carry out a proper survey by experienced personnel, taking proper precautions.

10 Training of operational personnel

10.1 General

Training should be provided for those maintaining, using or interpreting the results from gas detectors. A distinction is made between ‘Operator’ training for those using portable equipment or monitoring fixed equipment, and ‘Maintenance’ training, for the sake of clarity and for the fact that users of the equipment generally will not be responsible for its maintenance. It is important to establish these roles at a very early stage.

However there is training in fundamental limitations of the environment and equipment, and essential safety training, for all personnel who could themselves go, or are responsible for sending others, into the hazardous areas.

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

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

The training should also reflect the actual work environment and the responsibilities of the personnel concerned.

Periodic refresher training is strongly recommended.

Records of all training should be kept for a defined time span.

NOTE Some national regulations require training to be done by ‘competent persons’ as defined in those regulations, in a national training framework, or in national standards. Competency-based training of this type requires, in addition to instruction and practical hands-on experience, a formal assessment of each trainee by a qualified ‘assessor’ (who can be the competent trainer).

10.2 General training – Basic limitations and safety

For general training it is suggested that those parts of Clause 4 relevant to the site or application can be used as a basis, together with those sections of the vendor’s literature relevant to the function of the personnel concerned.

Certain minimum information on limitations should always include:

a) Flammable (combustible) gas equipment will only detect gases and vapours that are present in the vicinity of the detector (or in the line of sight of open path equipment).
b) It will only detect those vapours that do not condense at the temperature of the detector or its sampling equipment (where applicable).
c) Where liquid flashpoints are well above ambient temperatures vapours can only exist at low percentages of LFL.
d) Flammable gas equipment will not detect flammable liquids as such, or combustible mists, dusts, or fibres.
e) Many types of flammable gas equipment have varying sensitivity to a whole range of gases. If the gas detected is not the gas on which the equipment is calibrated, the reading may not be correct (i.e. higher or lower than the actual value).
f) Erratic indications may indicate equipment malfunction or some atmospheric disturbance. Where doubt exists, a check should be made with a second equipment and/or the equipment should be rechecked under controlled conditions before its continued use.
g) The occasional or continuous presence of low concentrations of the gas of interest will produce indications that could be mistaken for zero drifts. In case of doubt, the equipment should be rechecked using clean air.
h) If off-scale readings in either direction are observed, It should be assumed that a potentially explosive atmosphere is present until proven otherwise (e.g. by checking with a second equipment, applying clean air and then rechecking, etc).
i) Some flammable gases and all vapours (except water) are toxic at low levels of concentration. The potential toxicity should be known, and necessary precautions taken.
j) In confined spaces there may be oxygen deficiency, which in turn might be due to toxic substances. Confined space entry is a specialised operation and requires specialist training.
k) If probing or sampling via a tube from confined spaces, a severe oxygen deficiency can cause the more common types of flammable (combustible) gas equipment to misread.

10.3 Operator training

In the simplest case for users of portable equipment, there is the training for “Read and run” operations (see 9.1 and 9.3.9). This, however, requires that the person directing the operator is sufficiently well trained to be responsible for the safety of the operator in the particular circumstances under which the operator will, or could possibly, be working.

For advanced users of portable equipment and for operators using fixed systems, the training should be designed to ensure understanding and familiarity of equipment, the working environment and the system. It should advise and show operators how to make visual and functional checks, and whom to contact in the event that the equipment is suspected of malfunctioning.

It is particularly important that operators have instructions to be followed in the event of a gas alarm.

Periodic (e.g. annual) refresher training should be given. This is vital in situations or applications where alarms seldom occur.

Instructions should be drafted prior to installation of a fixed system or the introduction of portable detectors to cover actions to be taken in the event of alarms, other safety considerations, and the personnel who should be informed if a malfunction is suspected.

10.4 Maintenance training

Maintenance training should be designed for those charged with inspections, maintenance and calibration. In addition to providing all information necessary to perform these tasks, it should include some understanding of detector function, etc. Manufacturer’s literature is essential.

11 Maintenance, routine procedures and general administrative control

11.1 General

Routine maintenance of any flammable gas detection system is an extremely important factor affecting the reliability of the units. Optimum system performance and reliable operation will only be achieved if there is informed management, producing a responsible and practical programme which yields complete, dedicated maintenance on a high priority level.

Management of such a program depends on setting responsibilities for the various aspects (e.g. who is supposed to perform functional checks, who is supposed to perform inspections and re-calibrations, and who is responsible for maintenance), and then ensuring that the personnel concerned are adequately trained and periodically retrained. Part of this management responsibility is setting operational limits (e.g. determining acceptable tolerances on functional checks that are to be permitted before re-calibration becomes mandatory, determining the frequency of regular re-calibrations, the frequency of maintenance etc).

Records should be made and filed for all inspections, verifications, tests and work done on the detection system. An excellent means of keeping records for the system which also aids in keeping abreast of the required maintenance tasks, such as calibration, is the use of certain computer programmes. In the simpler cases, refer to Annex D for a typical maintenance record.

Gas detection equipment should be individually identifiable. Portable and transportable equipment should be marked with an identification of the calibration date and, according to the control system employed, the length of time to the next re-calibration.

Flammable gas detection equipment or systems vary in application from portable units taken to sites where gas/air atmospheres are expected to be present, to fixed systems which may rarely sense a gas/air mixture in their working lifetime.

Inadequate maintenance, incorrect zero adjustment and, in portables, deteriorated batteries are all causes for errors in gas detection. It is important to remember that errors and failures in gas detection equipment or systems may not be self-evident, and therefore gas detection should be only part of the overall strategy for plant and personnel protection.

The reliability of the measurement depends on the use of test (calibration) gas, essentially duplicating its entire function. All types of equipment whether portable, transportable or fixed (including both point and open path types) should be checked at regular intervals with the test gas recommended by the manufacturer.

When it is necessary to detect the presence of several gases mixed with air, the sensitivities to these gases should be checked periodically with appropriate test gases.

A recalibration should be performed regularly by the plant instrument maintenance personnel, or their equivalent, on every portable equipment or fixed sensor (detector head). Records should be maintained for each portable equipment or detector head.

The time intervals at which these procedures should be carried out will depend upon many factors including: the nature of the equipment, i.e. whether portable, transportable or fixed; the detection technique employed; the prevailing environmental conditions at the installation; the previous history of performance; and reliability in the application concerned.

Regarding calibration, gas detection equipment should be:

1) regularly inspected for possible malfunctions, damage or other deterioration;
2) calibrated in accordance with the manufacturer's instructions, using the recommended test kit/equipment (see 8.11);
3) if fixed, calibrated on commissioning and tested/re-calibrated at defined intervals thereafter; for new installations it may be prudent to carry out such procedures frequently at first (perhaps weekly), increasing the time intervals (to, perhaps, monthly) as confidence grows with experience in the installation concerned, on the basis of the maintenance records;
4) if portable, frequently functionally checked in accordance with 9.2.2, or re-calibrated in accordance with 9.2.3 . In arduous or unknown situations or where the equipment is not frequently used, this should be done immediately before each occasion of use. Where “gas-free” or “permit to work” certificates need to be issued a functional check should be carried out prior to use and the result should be recorded on the certificate. It is strongly recommended to perform at least the functional check after use, and to record this result as well on the certificate. In less demanding situations, the guidance in (item 3) above should be used;

   NOTE 1 The instruction manual of portable equipment complying with IEC 60079-29-1 is required in 4.4 of that standard to provide a method for performing a functional check with gas before each day of use.

5) calibrated to the gas for which they are least sensitive if several gases are likely to be present.

It is acceptable to use a calibration gas, different from that monitored, provided that an appropriate correction is made, so that the detectors when calibrated give the correct response to the monitored gas. However, if methane is one of the gases that could be detected, use methane in air calibration gas.

To ensure that the hazardous area certificate is not invalidated, any repair or maintenance that involves the explosion-protection of the equipment should not be carried out without full instructions and drawings from the certificate holder. Preferably the equipment should be returned for repair to the certificate holder. The requirements included in IEC 60079-17 and IEC 60079-19 shall be accepted.

NOTE 2 In many countries, the legal liability for maintenance of certification on equipment may rest with the owner/user.

Equipment awaiting re-calibration or maintenance should be kept separately from equipment awaiting return to service after such operations.

Spares may deteriorate in storage owing to mishandling or age and should always be tested before use. In particular, care should be exercised with optical surfaces.

Process modifications that result in different concentrations of flammable substances and/or the use of different flammable substances can result in dangerous situations. Before such changes are performed, re-evaluation of the suitability of the equipment in use and its calibration is necessary.

11.2 Operational checks

11.2.1 General

The following inspections and tests should be made on a regular basis as specified below to maintain the reliable operation of the gas detection system.

If the status of an equipment is not known, it should be checked prior to operation.

11.2.2 Fixed systems

a) Regular visual inspection.

   Regular inspection of the control panel should be made. Records made of each check, including any problems, should be signed, dated and filed. Problems found should be corrected promptly.

b) Regular functional verification.

   Regularly, verification of the control and alarm panel should be made using test switches to ensure that lights, alarms and electronics are operating normally. This functional verification will vary depending on the unit used. Problems found should be corrected promptly.

c) Regular re-calibration .

   This test is of vital importance to the ongoing reliability of the system. In the case of sensor-based systems, it is necessary to subject each sensor to the calibration gas, thus allowing a complete loop check of the electronics and the sensor. By maintaining accurate records of information about system patterns, particularities, component life, etc., potential problems can be averted before they develop.

   In the case of open path equipment, the entire path length needs to be verified gas free for a valid zero check. Typically this requires a high sensitivity portable gas detector. A span check is then performed using a sealed sample of calibration gas in a cell with transparent ends, or a functional check is then performed using a pre-calibrated optical filter.

d) System operation test

   For the system operation test, the whole safety function starting at the gas inlet or measuring point until the final element responsible for a safety action should be checked for proper function. The response time for the detector or measuring point (including gas transport) should be compared with the original specification.

   In the case of systems using sampling tubes this translates into regular re-calibration of the central analyser(s) and of derived alarm circuits. Periodically the integrity of the sample system and each individual sample line should be checked by applying the test or calibration gas, at atmospheric pressure, directly to the sample point and verifying that the same result is obtained as when applying the same gas to the analyser(s). In this case the gas shall not be pressurised: Easy means of doing this include the use of thin plastic bags or bladders of the gas, applying the gas from some sort of flow regulator at a higher flow than the sampling rate, with a blow off to atmosphere for the extra flow, or the use of a demand regulator.

   NOTE 1 This is the most important test to be made on the system for all sites at the time of installation and again at regular intervals. Guidance may be obtained from the manufacturer.

NOTE 2 The system operation test for the whole safety function is identical to the proof test required for safety systems compliant with functional safety standards (e.g. IEC 61508).

e) Complete the maintenance records. Refer to Annex D for a typical maintenance record.

11.2.3 Portable and transportable gas detection equipment

a) Visual inspection.
   1) Check the equipment for abnormal conditions such as malfunctions, alarms, non-zero readings, etc.
   2) Ensure that the detector head assembly is free of obstructions or coatings which could interfere with the gas or vapour reaching the sensing element. Ensure that the sample drawn is correct for sample-draw systems.
   3) For sample-draw systems, inspect flow lines and fittings. Cracked, pitted, bent or otherwise damaged or deteriorated flow lines or fittings should be replaced with those recommended by the manufacturer.

b) Sensitivity checking.

   This should be, at least, a functional check or a re-calibration. Either of these consists of:

   (i) Ensuring that the equipment indicates zero when zero gas is present; temporarily isolating the sensing element if necessary.
   (ii) Applying a known calibration gas to the detector head, following the manufacturer's instructions.

   The difference between the functional check and re-calibration is that in the former, some tolerance in readings is given by the person managing the gas detection and adjustment is not made when the calibration gas is applied, although a zero adjustment may be permitted. This check should ideally be performed by the operator.

   In the case of a re-calibration, this should be done on a planned regular basis and also if a functional check is outside the permitted limits. The responsibility for this may be placed with maintenance personnel.

c) Complete the maintenance records. Refer to Annex D for a typical maintenance record.

11.3 Maintenance

11.3.1 General

Maintenance operations should not compromise safety in the area being protected.

Maintenance procedures should be undertaken only by personnel trained in the operation, maintenance and repair of flammable gas detection equipment.

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 equipment to the manufacturer or other qualified outlet for repair.

Complete, explicit instructions for testing and checkout of replaceable equipment components may be obtained from the manufacturer. Suitable parts lists are provided in the instruction manual.

After any defective operations are corrected (repaired or replaced in strict accordance with the manufacturer's instructions), a full workshop calibration test, as described in 11.8, should be conducted.

11.3.2 Fixed equipment

Repair or maintenance of fixed equipment (whether incorporating single-point sensors, open-path sensors, a combination of these, or sampling systems) should be carried out under a controlled procedure. Defective equipment should be removed for repair in a workshop outside the area being protected. If replacement equipment cannot be provided immediately, then transportable equipment should be used as a temporary substitute.

11.3.3 Portable and transportable gas detection equipment

For portable and transportable gas detection equipment, it is important that the whole unit be removed to a non-hazardous location for repair and testing.

11.3.4 Off-site maintenance, general

Defective units should be:

a) returned to the manufacturer;
b) returned to a repair agent authorized by the manufacturer;
c) repaired in a special workshop set up by the user for gas detector maintenance, or
d) permanently taken out of service.

11.3.5 Maintenance procedures

11.3.5.1 General

Given the variety of equipment available, it is not practical for this standard to tabulate each maintenance, repair and calibration step in detail. What follows is a listing of the principal items that all maintenance procedures should include.

11.3.5.2 Procedure

If an equipment is in the workshop for scheduled maintenance, the full maintenance procedure should be conducted. If specific equipment failure is the cause of return, the complaint should be noted and only applicable check-out tests need to be conducted. However, all equipment should undergo a full calibration test before being returned to service.

11.3.5.3 Record

The maintenance record for the equipment should be reviewed for previous service history. See Annex D for typical equipment maintenance record for flammable gas detectors.

11.3.5.4 Failure

When receiving a failed equipment, it should be determined if the equipment power supply (including any voltage regulation stages and/or battery chargers supplied) is the primary cause for failure before proceeding further.

11.3.5.5 Replacement/Repair

After checking the power supply, repair personnel should proceed with the checkout of sensors, flow systems readout devices and alarm devices – identifying and correcting all deficiencies. 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.

11.4 Sensors

11.4.1 General

Depending on the time interval since the last sensor replacement, anticipated field usage, and response to the gas mixture during calibration, good maintenance practice suggests sensor evaluation/replacement at service intervals recommended by the manufacturer. It is further recommended that sensors be evaluated after exposure to high concentrations of flammable gas or after severe impact or mechanical vibration has occurred.

11.4.2 Flame arrestor

If a flame arrestor is part of the sensor assembly, it should be checked for proper attachment and fit, and signs of corrosion, dirt or moisture. Any necessary cleaning or replacement should be in accordance with the manufacturer's instructions.

11.5 Flow systems

11.5.1 General

This subclause is applicable only to equipment utilizing aspirated sampling.

11.5.2 Inspection

The flow system shall be checked for leakage, restrictions, and proper aspirator bulb or electrical pump operation. Any necessary cleaning, repair or replacement should be in accordance with the manufacturer's instructions. A cause for leakage can be cracked or otherwise damaged pump diaphragms or piston rings as appropriate to the pump type.

11.5.3 Filters, traps and flame arrestors

All filters, traps and flame-arresting assemblies should be emptied, cleaned or replaced in accordance with the manufacturer's instructions.

11.5.4 Flow system and sample chamber

The flow system and sample chamber should be examined for deposits of foreign material and steps taken to prevent future occurrences.

11.5.5 Flow connections

All flow connections should be tightened in accordance with the manufacturer's instructions.

11.5.6 Moving parts

All valves and moving pump parts should be lubricated *only* according to the manufacturer's instructions.

Silicone compounds typically should not be used for this purpose; check with the manufacturer if there is any question regarding the acceptability of silicone compounds or other materials.

11.5.7 Automatic sample-draw systems

Automatic sample-draw systems should be adjusted to correct flow rate values using recommended test equipment.

11.5.8 Loss-of-flow signals

The loss-of-flow signals should be checked for proper operation.

11.6 Readout devices

11.6.1 General

If the equipment incorporates a meter, perform the following procedures:

a) inspect the meter for broken or cracked lens;

b) inspect analogue meters for defects – for example bent pointers, loose dials, loose end stops, etc.;

c) inspect digital meters for defects – for example missing segments, faded segments, etc.;

d) conduct other electrical and mechanical meter tests which the equipment manufacturer deems necessary to assure proper performance.

11.6.2 Other readouts

Other readouts (for example solid state) and outputs (for example alarm outputs) which may be incorporated should be tested (electrically) at specified test points according to the manufacturer's instructions.

11.7 Alarms

If alarms are incorporated, check for proper alarm operation by offsetting electrical zero (or by other methods as recommended by the manufacturer) until the alarm(s) is(are) initiated. Check failure (malfunction) circuits by disconnecting components (or other actions recommended by the manufacturer) and observing whether or not the failure alarm operates.

11.8 Calibration

11.8.1 Calibration kits and test equipment

All calibration mixtures and associated calibration equipment should have appropriate characteristics to ensure reliable results. The essential components of calibration equipment are as follows:

a) A calibration gas mixture is required, under pressure in a cylinder. This is normally, intended to give a specific response usually somewhere between 25 % and 90 % of full scale on the gas detector. Typically this is certified or analysed to be accurate to at least ±5 % of the actual labelled concentration. The cylinder may be specially treated internally if the calibration gas is intended to simultaneously calibrate a flammable gas sensor and a sensor for a toxic reactive gas.

b) In some cases, equipment calibrated for a flammable vapour cannot readily be provided with stable calibration mixtures in the form of compressed cylinders or low-pressure containers. In these cases, the manufacturer should provide relative response data to permit the use of more commonly available gas mixtures for calibration.

c) A suitable regulator assembly is required to reduce compressed cylinder pressure. Depending on the gas detector to be calibrated this can have outputs of a pre-set or adjustable low pressure. However in many cases the calibration gas has to be supplied without pressurisation to the sensor, so the regulator and other equipment may be necessary to permit adjustment of flow rate to the equipment manufacturer's specified value.

d) For aspirated equipment, traditional methods, providing gas at atmospheric pressure to simulate normal sampling, use bladders inflated with calibration gases. Alternatively the regulator is chosen to provide a higher flow than the aspirator will draw and there will be a blow-off tube to atmosphere for the surplus flow. More recent equipment has a demand regulator incorporated in the pressure regulator c) above, so that it delivers gas as required if a slight negative pressure is applied to its output.

e) For diffusion equipment and some aspirated equipment, the regulator in c) above is configured as a flow regulator, either pre-set with or without flow indication, or adjustable and equipped with a flowmeter.

f) For connection to aspirated equipment a tube is usually all that is required. However special calibration adapters are required for diffusion types of equipment. These are designed by the gas detector manufacturer to ensure that the calibration gas mixture surrounds the sensor(s) and keeps ambient air out. But more importantly, by the combination of their design and a designated controlled flowrate, they are designed to produce the same response on a test gas as would be obtained using the same gas in their normal diffusion mode.

g) For open path equipment, calibration can be confirmed using a gas test cell in the field. This test cell is filled with a calibration gas consisting of the gas of interest in nitrogen. The calibration gas concentration multiplied by the cell length gives the required integral concentration. More commonly, a functional check is routinely performed with a pre-calibrated optical filter supplied by the manufacturer. In either case this is interposed between transmitter and receiver, or between the transceiver and retroreflector.

   At all times care should be taken to avoid any damage to the pre-calibrated optical filter. Even slight folds, creases, scratches, or dust, finger prints or other contaminants will distort the reading considerably. Multiple pre-calibrated optical filters in series should not be employed.

h) The calibration system should be resistant to absorption of, and corrosion by, the calibration mixture. This can necessitate the use of special materials, particularly where sensors for reactive toxic gases, such as H_2S or Cl_2, are incorporated with flammable gas detectors.

i) Some modern portable gas detectors with internal microprocessors and data links have dedicated gas calibration equipment with data links capable of producing test reports on an associated computer, running vendor-supplied software. This may also produce specified readings based on relative response data.

j) In other cases, particularly fixed equipment, there is a hand-held controller with a data link capable of communicating with the equipment and making the adjustments.

k) In many of these last two cases, there is a program that requires a very specific calibration gas mixture applied in a particular way, particularly flowrate.

In view of all of these variables, when determining the gas and equipment necessary to calibrate such sophisticated gas detectors the first, and perhaps only, choice must be the equipment recommended by the vendor for that particular model of gas detector.

11.8.2 Calibration procedure

11.8.2.1 General

The calibration equipment or kit should be chosen as in 11.8.1 of this standard.

11.8.2.2 Gas mixture

All tests should be conducted in a manner to ensure safe venting of calibration mixtures.

11.8.2.3 Stabilization

Equipment should be allowed to stabilize at operating temperature, and then operating controls should be adjusted in accordance with the instruction manual.

11.8.2.4 Zero check

It is usual to conduct a zero check using clean air, or, where the air cannot be guaranteed to be uncontaminated, using zeroing gas (usually dry air) from a cylinder, and the rest of the calibration equipment as in 11.8.1.

11.8.2.5 Span calibration

The calibration system should be connected to the equipment and the final span reading noted. The calibration should be adjusted, if necessary, so the output reading equals the concentration of the calibration mixture, or a predetermined readings In some cases, this may be performed automatically. The calibration mixture should be removed, and it should be ascertained that the equipment returns to "zero." This procedure may require repeating if the equipment zero and span adjustment interact.

When a target gas is not available for gas sensor calibration it is possible to use a surrogate gas. Surrogate gas calibrations may be less accurate and may not deliver the desired response rate. The use of surrogate gas calibrations should be as advised by the manufacturer.

11.8.2.6 Alarm verification

Ascertain that any/all alarms are actuated when the set point(s) is (are) reached. The manufacturer's recommendations should be followed when selecting the calibration mixture for equipment with alarms, as the concentration required is usually slightly higher than the nominal alarm setting (to guarantee prompt alarm actuation).

11.8.2.7 Maintenance record

The calibration test herein described shall be the last conducted before equipment is released from the workshop. It is recommended that the calibration data be recorded on the instrument maintenance record. The instrument maintenance record (or comparable document) should be updated before returning the equipment to service. See Annex D for a typical instrument maintenance record for flammable gas detectors.

Annex A
(normative)

Measuring principles

A.1 General

The measuring principles of various types of sensors are given below in more detail than in Clause 5 for the main benefit of engineers and managers for selection, design and installation as well as trainers. This annex provides the advantages, common applications and limitations for nine generic types of gas sensors. The limitations include interference and substances causing loss of sensitivity (poisons).

It is useful for engineers and managers to know the measuring principles of gas sensors and/or gas sensing elements, when they decide the suitable gas detector for the intended application after talking with manufacturer or seller. However, the performance and function of the gas detector will not be decided only by the gas sensor or the gas sensing element applied to it. Therefore, it should be in mind that the selection of the gas detector should be done considering the total performance and function assisted by the peripheral hardware and software.

By their very nature, catalytic sensors in A.2 and the flame temperature analyser (FTA) in A.8 directly detect flammable gases by burning and therefore can not detect non-flammable gases and vapours. The other types of sensors described later in this section indirectly infer the presence of flammable and other gases by the response of the sensor to other gas properties.

For the convenience of the reader, Table A.1 is a copy of Table 2 in 5.1 with references changed to suit this annex.

Table A.1 – Overview of gas detection equipment with different measuring principles

	Catalytic sensor	Thermal conductivity sensor	Infrared sensor	Semi-conductor sensor	Electro-chemical sensor	Flame ionisation detector	Flame temperature analyser	Photo ionisation detector	Para-magnetic oxygen detector
Details in clause	A.2	A.3	A.4	A.5	A.6	A.7	A.8	A.9	A.10
O_2 required in gas sample	Yes	No	No	(No)	(No)	(No)	Yes	No	Not applicable
Typical measuring ranges for flammable gases	≤ LFL	(0) to 100 % FS	0 to (100) % FS	≤ LFL	≤ LFL	≤ LFL	< LFL	< LFL	Not applicable
Typical measuring range open path	Not applicable	Not Applicable	0 to 5 LFL.m	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Typical measuring ranges for oxygen	Not applicable	Not applicable	0 to (100) % FS (with special sensing elements)	Not applicable	0 to 25 % (0 to 100 %) FS	Not applicable	Not applicable	Not applicable	0 to 100 % FS
Flammable gases not measurable	Large molecules	(See A.3)	H_2	(See A.5)	Alkanes	H_2; CO	(See A.8)	H_2; CO; CH_4 IP>X[e]	Flammable gases
Relative response time[a]	Depends on substance	Medium	(Low)	Depends on substance	Medium	Low	Low	Low	Low to medium
Interference of non-flammable gases[b]	No	CO_2; Freons	(Yes)	SO_2; NO_x H_2O	SO_2; NO_x	ClHCs[c]; Halon	(Halon)	Substance IP < X[e]	NO; NO_2
Poisoning[b]	Si; (Hal[d]); (H_2S); Pb	No	No	Si; Hal[d]; SO_2	(No)	(Si)	No	No	No
External gases required	No	No	No	No	No	Yes	Yes	No	(Yes/No)

[a] Qualitative comparison between principles. The values do not take into account time for aspirated sampling lines.

[b] Table gives common examples.

[c] Chlorinated hydrocarbons.

[d] Organic halogenated or inorganic halogen compounds.

[e] IP is the ionisation potential of the substance; X is the detector UV-lamp energy.

The statements in brackets are conditional and reference should be made to the corresponding subclause.

NOTE The term ‘Full Scale’ is denoted as “FS”.

Alternative detection technologies can be considered. However, the limitations of these alternative technologies must be assessed with respect to their ability or inability to determine the concentration of gas. Therefore, the hazard potential should be clearly understood in a safety system. As a consequence, alternative technologies which do not comply with gas measurement performance standards (e.g. IEC 60079-29-1 or IEC 60079-29-4) should only be considered as supplementary detection methods. For instance, ultrasonic detectors are available for detection of the presence of leaks particularly from high pressure sources. However, their characteristics are such that the earlier stages of a leak can give a stronger signal than a more developed leak with a higher flow rate. Therefore, such ultrasonic detectors should be regarded as a useful supplement to gas detectors, but in no way should be regarded as their replacement. Another example would be the use of infrared cameras which show location and rough extent rather than the gas measurement concentration.

A.2 Catalytic sensors

A.2.1 General

The principle of operation of catalytic sensors depends upon the oxidation of flammable gas on the surface of an electrically heated catalyst typically operating at a temperature between 250 °C and 550 °C. The catalyst is usually in the form of a filament of catalytic material (e.g. platinum) or as a porous ceramic bead, impregnated with catalytic material, surrounding a heater filament. The latter is frequently referred to as ‘Pellistor’ or ‘bead type catalyst’ and is the type of device most commonly used in recent years.

This oxidation causes a measurable temperature increase of the sensing element approximately proportional to the concentration of flammable gas detected. The sensing circuit is normally constructed as an electrical half-bridge with two electrically similar filaments or beads mounted close to one another, one is active and the other is inactive. This second, usually non-catalytic element acts as a reference, so that effects of pressure, temperature and humidity may be compensated out and have no significant effect within the specified range.

The resultant change of electrical resistance in the active sensor is then electrically converted to the output signal, usually by unbalancing a Wheatstone, or similar, bridge arrangement.

The fact that an oxidation reaction occurs means that both the flammable sample and oxygen are consumed by the process and have to be continually replaced, and the products of combustion have to leave, either by a diffusion process or in an aspirated sample stream.

In the case of ceramic ‘bead type catalyst’, diffusion of reactants in and products out of the bead itself become rate-determining at high concentrations, leading to saturation and anomalous behaviour somewhat above the LFL.

A sufficient concentration of oxygen in the surrounding atmosphere, in the order of 10 % v/v or greater, is required for catalytic sensors to operate.

For these reasons, detection equipment with this type of sensor should be used only for gas concentrations up to the lower flammable limit in normal atmospheres.

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, which either produce a layer of solid products of combustion on the catalytic surfaces, or otherwise modify the surfaces. 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.

Catalytic sensors, particularly the bead types, are capable of continuous operation for a few years in the absence of major poisoning, but will progressively drift and lose sensitivity due to ageing and traces of poisons. For this reason regular response checks and recalibration are required, the frequency depending on the severity of the application.

Sensor enclosures in most cases incorporate a permeable metal device to allow gas to reach the sensing element. This also ensures that, if the gas concentration is above LFL and may be ignited by the hot sensing elements, the atmosphere outside the enclosure is not ignited. This protection is also useful against dust or mechanical damage, as well as protection against excessive air velocities.

A catalytic sensor may be used in either

a) diffusion mode; or

b) aspirating (electrically or hand-pumped) mode.

A.2.2 Common applications

Catalytic sensors are suitable for the detection of gas/air mixtures up to the lower flammable limit (LFL). They will detect in principle all flammable gases, but with variations in sensitivity.

The response time and sensitivity depend on the individual gas to be measured. The larger the molecular mass and molecular size of the gas, the longer will be the response time, and generally, the lower will be the sensitivity.

A.2.3 Limitations

The catalytic sensor depends upon catalytic oxidation and it functions only when sufficient oxygen is present. Insufficient oxygen concentration may occur at high flammable gas concentrations well above the LFL or by inert gases. Therefore, this type of sensor can only be used for the detection of gas/air mixtures up to the lower flammable limit.

WARNING – With concentrations above the lower flammable limit, a catalytic sensor may erroneously indicate that the concentration of flammable gas is below the LFL.

Therefore, equipment fully complying with IEC 60079-29-1 using catalytic sensors must have a locking overrange indication to prevent erroneous readouts due to this limitation. However, gas detection transmitters (e.g. 4 mA to 20 mA transmitters) and older equipment may not provide such protective features.

NOTE In case of gas detection transmitters not providing a locking function of the overrange signal the locking has to be provided by the central unit to comply with IEC 60079-29-1.

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.

Changes of pressure, temperature and humidity have only limited effect within the specified range. However the lower the alarm level is set the greater will be the significance of variations in temperature and other environmental factors.

To prevent false alarms, it is recommended that the alarm level should not be set below 5 % LFL for methane, 10 % LFL for propane and butane and 20 % LFL for gasoline vapours, provided suitable precautions are taken against toxicity in the last case.

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

For reasons given in the last three paragraphs, the sensors are not suitable for high sensitivity applications (e.g. ranges much less than 0 to 10 % of LFL), as amplification would merely amplify these undesirable features.

A.2.4 Interferences

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

If the atmosphere to be monitored contains gas or gases that dilute or displace air, for example nitrogen or carbon dioxide, the catalytic sensor may give a low or even zero response. Similar problems may occur in steam-laden atmospheres, quite often owing to saturation of the sintered flame arrestor due to condensation. High concentrations of inert gas (for example argon or helium) may also change the thermal balance of the sensor resulting in apparent reading of flammable gas.

A.2.5 Poisoning

Catalytic sensors are susceptible to poisoning by substances many of which are not obviously present but are fairly widely used, necessitating regular response checking and recalibration.

This inhibition may be permanent or temporary according to the nature of the contaminant.

Permanent inhibition, usually known as "catalyst poisoning", may result from exposure to such substances as:

- silicones (e.g. waterproofing, adhesives, release agents, special oils and greases, certain medical products);
- tetraethyl lead (e.g. leaded petrol, particularly aviation petrol ‘Avgas’);
- sulfur compounds (e.g. sulfur dioxide, hydrogen sulfide);
- halogenated compounds (e.g. some halogenated hydrocarbons);
- organo-phosphorus compounds (e.g. herbicides, insecticides, and phosphate esters in fireproof hydraulic fluids).

In some cases, halogenated hydrocarbons and sulfur compounds may only cause temporary inhibition.

So-called "poison resistant" sensors can tolerate higher doses of these contaminants than traditional sensors before they suffer inhibition. In achieving this, their other properties may suffer (e.g. they may have a lower speed of response and reduced sensitivity).

Those that are not “poison resistant”, in some cases, may be protected against most poisons by the use of activated carbon or other types of filter. However, filters should be used with great care because, while they may offer excellent protection from contaminants, carbon filters in particular will cause a reduced sensitivity to, and may even prevent the detection of, higher hydrocarbons. They might also result in considerably extended response times for substances other than methane or hydrogen, effectively limiting their application to these gases. Filters have a limited lifetime and require replacement. Their performance may also be affected by the level of humidity in the atmosphere.

An alternative technique sometimes used to reduce the effects of poisoning is the electrical operation of the sensor in an intermittent mode. This technique may also be used to reduce battery consumption. However, there are circumstances in which such sensors may give a false response, for example when they are suddenly exposed to a high concentration of gas during the "power-off" part of the switching cycle. Particular caution is necessary when using such portable equipment in leak-detection mode or in similar operations.

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

A.3 Thermal conductivity sensors

A.3.1 General

The principle of operation of the thermal conductivity sensor depends upon the heat loss by conduction (and sometimes convection or mass transport as well) of an electrically heated resistance element (i.e., filament, bead or thin film resistor) located in a gas sample stream of constant flow rate, or in a diffusion chamber.

A considerably lower temperature is required for this type of sensor than for catalytic types. Consequently sensor life is essentially indefinite in the absence of corrosion or contamination.

The sample is not consumed or altered by the sensor, and it does not require oxygen.

The temperature of the element, 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. When there is a change of gas composition the filament temperature changes and the resulting change of electrical resistance is then determined in a similar manner to catalytic sensors (see A.2). Usually, there is a compensation element in a reference gas stream, or sealed reference gas, to eliminate the influence of external temperature fluctuations.

This type of sensor is suitable for monitoring those gases whose thermal conductivity in the desired detection range differs greatly from that of the reference environment (usually air). However, published tables of thermal conductivity may be misleading as other effects like convection or mass transport also influence the sensitivity of the sensor.

This limits the technique to relatively high concentrations, usually above the lower flammable limit. Equipment incorporating thermal conductivity sensors should not be used for measuring gas concentrations below the LFL except in the case of gases such as hydrogen for which such sensors are especially sensitive.

The response to a gas mixture is indeterminate unless the proportions of all the constituent gases in the mixture are known and stable, including gases not required to be detected. In the worst case, a mixture of high and low thermal conductivity gases, for instance caused by a variation in the background gas from the intended background, could cancel out the response of the gas of interest.

A.3.2 Common applications

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

The equipment may be calibrated in any suitable range up to 100 % of a nominated gas in a nominated background gas.

These sensors are suitable for detecting individual gases of high or low conductivity, relative to air, where air is the reference environment. Typically the high conductivity gases hydrogen, helium and neon have a good sensitivity in air, and the sensitivity for methane is usually acceptable.

The sensitivity is often limited and practical measuring ranges will be well above LFL unless the thermal conductivity of the gas is sufficiently different from that of air.

A special application is for the purging of LPG tanks with CO_2/N_2 'inerting' gas. When thermal conductivity is combined with convection it is possible to produce sensors which are largely independent of a range of background gases (e.g. air, nitrogen and certain carbon dioxide / nitrogen 'inerting' gases). At the same time these will respond with at least comparable sensitivities to a range of lower hydrocarbons from methane to pentane, although thermal conductivity data alone would indicate that this is not possible.

A.3.3 Limitations

The technique is limited to applications where anticipated variations to the background gas have a negligible effect when compared to the response(s) of the gas or gases of interest in the required range.

The sensors are not selective for individual gases. They will respond to all gases whether flammable or not.

The thermal conductivities of flammable 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 all the constituent gases in the mixture are known and stable. In the worst case, a mixture of high and low conductivity gases could cancel each other out and produce no equipment response.

Errors may also result if:

a) a flow-sensitive type of thermal conductivity sensor is used and the gas sample flow is not stable, or if the recommended conditions of gas flow are not maintained as per the manufacturer's instructions;
b) there are variations in ambient temperature without compensatory ambient temperature control on the complete sensor;
c) the equipment is used in an unintended orientation, particularly if it is a type employing convection as well as conductivity.

A.3.4 Interferences

Interference or errors will be caused if the equipment is exposed to, or is used to attempt to detect, gases for which it is not calibrated. Specifically additional or unanticipated gases whether flammable or not, of different thermal conductivities to the background can affect the resulting conductivity in either direction, so that the signal may even be reduced to zero.

A specific interference in many cases is water vapour since it can be highly variable, particularly in hot climates. In the higher sensitivity applications the signal due to likely water vapour variations may be sufficient for the equipment to require sample conditioning.

A.3.5 Poisoning

There are no known poisoning effects.

A.4 Infrared sensors

A.4.1 General

The principle of operation of optical sensors depend upon the absorption of energy of a beam of light, in the ultra violet, visible, or infrared parts of the spectrum, by the molecules of the gas being detected. Most existing equipment operate within the infrared (IR) spectrum.

Most gases absorb infrared energy. The exceptions are monatomic gases (e.g. helium, neon and argon) and symmetrical diatomic gases (e.g. hydrogen and nitrogen). Oxygen is unusual in that it has a weak absorption at a wavelength not normally used for detection of any other gas.

All other gases will absorb infrared energy, to a greater or lesser extent, at their own bands of wavelengths which are characteristic for the types of chemical bonds in them. Selecting appropriate bands for detection in equipment provides a means of achieving selectivity.

This measuring principle is therefore of great use in monitoring most other gases in air, since the three major components of dry air; nitrogen, oxygen and argon, have a negligible effect on both zero and upscale readings in the band of wavelengths commonly used.

Characteristic bands of wavelengths are similar for families of compounds. For instance there are bands characteristic of hydrocarbons and many other organic substances that are particularly useful for flammable gas detection, since equipment selecting these can detect all of these compounds with varying sensitivities.

However, there are many cases where there is overlap of the absorption bands of non-flammable substances and other substances that may not be required for detection, the most common being water and carbon dioxide. If these overlapping wavelengths cannot be adequately filtered in the equipment there will be interference from these substances.

Infrared sensors do not consume the sample, and they do not require oxygen for their operation. They are largely unaffected by flow rate. Sensor life is expected to be long in the absence of corrosion, contamination or mechanical damage.

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

Detection equipment with infrared sensors may take various forms but may be categorized as:

a) specifically adapted analysers with sampling systems, which may have multiple sampling lines;
b) single-point or portable, self-contained infrared detection equipment suitable for installation in potentially explosive atmospheres. These may have closed cells with internal pumps, or diffusion screens permitting sample to enter. Alternately they may have fixed paths essentially open to the atmosphere. In all cases the optical path is typically less than a metre in length.
c) light "pipes" – for example a fibre optic cable which directs an infrared light source from a control unit to a sensor cell at a remote location;
d) open path equipment, with a transmitter and a receiver at the ends of an optical path of variable length up to several hundred metres in the open air.

Performance aspects of (a), (b) and (c) are covered in IEC 60079-29-1. Performance of open path equipment is covered in IEC 60079-29-4.

In all cases infrared light from a source passes along an optical path through the gas and, after optical filtering, reaches an optical detector. The light source may be a filament such as a (tungsten) bulb lamp or a light emitting diode (LED) usually emitting in the near infrared region. In the case of open path equipment infrared lasers may be used.

In order to obtain a proper percentage of LFL output gas indication, as in cases (a), (b) and (c), a homogeneous mixture is required in the optical chamber between source and detector. In view of the small dimensions involved this is essentially guaranteed. However in open path applications this is far from the case, as the gas in the optical path between the transmitter and receiver will seldom, if ever, be homogeneous, and the measurement has to be regarded as an integral or an average (see 4.6).

Unwanted effects due to temperature, interfering gases and vapours etc, and, in the case of open path, precipitation, direct and reflected sunlight and artificial light, have to be minimised. This is done by optical filtering and, in many cases, the use of twin infrared beams of slightly different characteristics, modulating or chopping the infrared energy, and other ways of obtaining a reference.

In all cases optical filtering is performed either by periodically bringing filters into the optical path or using static filters sharing parts of the path. Filters can be solid optical high pass, low pass, or band pass material. They can also be sealed cells with optical windows, containing high concentrations of those gases expected in the sample and most likely to interfere with the gas of interest, which will remove the interfering wavebands.

Frequently, the light beam is chopped or pulsed 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, opto-acoustical 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 equipment.

In the case of open path equipment, the potential of interference due to water vapour and carbon dioxide is proportional to optical path length, and is therefore potentially up to several hundred times more severe than for a point sensor. There are also the problems of dusts and liquid water as mist, fog, rain and snow.

These extra problems require special techniques which include the use of wavelengths around 2,2 μm, where the absorption by the gases of interest is weaker than the normal 3,3 μm, but where the response to water is relatively much weaker. This requires strong highly focussed, modulated beams such as lasers. A typical system uses the differential responses at two close wavelengths, one of which gives a larger signal to the gas of interest than the other, while having a similar response to water, sunlight, mists and dusts. By basing the readout on their relative signals, most of the interference due to these unwanted effects is eliminated. However this still requires a reasonable amount of the signals to get through to the receiver, so there is a limit to the tolerance of open path.

Annex E provides extra information on atmospheric visibility for users of open path equipment.

The principle of infrared equipment of all types allows the use of self-diagnostics to verify the response to the gas. Other advantages include

a) high stability capability;
b) no ambiguity at concentrations above the LFL;
c) immunity to poisoning effects;
d) reduced maintenance through self diagnostics. Automatic calibration, checking capabilities for malfunctions of the infrared source, and compensation for dirt accumulation on the optics, may extend operation periods between services. However, special consideration should be given to clogging of protective filters in the gas path since this will not normally be detected by self diagnostics.

A.4.2 Common applications

Infrared sensors are calibrated to detect a particular gas or, in some cases, a range of gases. Other gases will not be detected if their infrared absorption band is outside that of the sensor. Equipment incorporating such sensors should therefore be used only for the detection of gas mixtures for which they have been calibrated.

Infrared detectors can not respond to hydrogen. However they may be used for the detection of most other flammable gases, in any specified range of concentration from a few hundred parts per million up to 100 % v/v gas. The longer the optical path is made, the higher will be the sensitivity. For the IR-measurement of oxygen TLDAS (Tunable Laser Diodes Absorption Spectroscopy) devices are used for measuring ranges up to several %V/V or up to 100 %V/V.

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

- measuring the total amount of hydrocarbons, often using the waveband associated with the range of C-H vibrational transition;

  NOTE In measurement of total amount of hydrocarbons some specific substances e.g. acetylene may not be included.
- selective measurement of one single component (in a mixture);
- measurement down to parts per million levels;
- measurement up to 100 % v/v of flammable gas;
- measurement up to 100 % v/v of oxygen.

In the case of open path equipment, the applications are currently restricted by technology as described above to the lower alkanes, lower alkenes and lower alcohols. A typical range is 0 to 5 LFL·m.

Because of these complexities the measuring range and performance of all infrared systems should be selected according to each application.

A.4.3 Limitations

These sensors will not detect hydrogen.

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 equipment. This can be fast particularly in aspirated equipment. However, in practice, weather protection housings, gas filters and hydrophobic barriers, where fitted, will limit the response times attainable.

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 equipment, see instruction manual.

Some types of sensor relying on intermittent infrared beams or photoacoustic principles are susceptible to vibration.

Open-path designs may be sensitive to misalignment e.g. caused by shock and vibration.

Temperature effects are usually small but may increase or decrease the signal.

A.4.4 Interferences

Other components (flammable or non-flammable) may induce a signal. Serious errors are likely to occur with some detectors due to interfering gases such as carbon dioxide.

Variations of water vapour concentration in the background gas can cause interference with many applications, including general-purpose infrared flammable gas detectors. However, equipment for this purpose that complies with the requirements of IEC 60079-29-1 will have minimal interference with water.

Solid and liquid contaminants will also absorb infrared energy, causing interference or loss of sensitivity. It is important to prevent contamination of the optical components (e.g. windows and mirrors) by particulate matter or condensation. When particulate filters are used to keep optical components clean, they may become blocked under excessively dirty conditions.

Apart from water vapour, the optical path of open path equipment is also exposed to precipitation and dust, as well as to natural and artificial light which may have variations, such as scintillation off water or lightning. High resistance to interference from these factors is required in equipment that complies with IEC 60079-29-4.

A.4.5 Poisoning

There are no known poisoning effects.

A.5 Semi-conductor sensors

A.5.1 General

The principle of operation of the semi-conductor sensor depends upon changes of electrical conductance that occur by chemisorption on the surface of the heated sensing element when exposed to gas other than air. Gas concentrations are inferred by measuring the change of resistance.

The semiconducting material is usually metal oxide, often based on tin oxide. It is electrically heated up to a few hundred degrees Celsius. Electrodes are implanted or otherwise mounted on the surface.

Sensors are used for the detection of gases in any concentration and output signal increases with increasing concentration. However, increasing rate of the signal tends to become smaller with respect to increasing concentration. Therefore, they tend to have a non-linear calibration curve. In many cases, semiconductor sensors require oxygen to operate, and humidity or oxygen changes may affect 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 flammable 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 but aspiration may be used).

A.5.2 Common applications

Semiconductor sensors may be used for the detection of gases with measuring ranges from the parts per million level up to the LFL and even above.

They are suitable for leak detection, even at very low concentrations, and for alarm-only equipment.

A.5.3 Limitations

Semi-conductor sensors for flammable gases are generally non-specific, vulnerable to both humidity changes and interfering gases and may exhibit drift both of zero and span. Some gases, for example NO_2, produce negative signals.

NOTE 1 Normally, the manufacturer will give guidance on substances that will inhibit operation of the sensor or produce false indications.

New sensors may need a long "burn in time" (up to weeks) for stabilisation of zero and sensitivity before calibration. This process, commonly called 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.

NOTE 2 It may be possible to avoid this effect of high gas concentration by special design of the detector.

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

A.5.4 Interferences

The measuring principle is generally not selective. However, improved sensing elements may have some selectivity. Non-flammable gases may induce a negative (e.g. NO_2) or a positive signal.

There may be 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 LFL. Refer to the instruction manual.

A.5.5 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.

A.6 Electrochemical sensors

A.6.1 General

The principle of operation of electrochemical sensors depends upon the change of the electrical parameters of electrodes in contact with an electrolyte when a specific gas is present. The change in the electrical parameters occurs due to a chemical reduction / oxidation (redox) reaction of the gas of interest at the surface of an electrode.

Electrodes and electrolyte are usually confined in a cell with a semi-permeable membrane permitting gas molecules of all types to diffuse through to the electrode-electrolyte interface. In most cases a layer of a precious or semi-precious metal is deposited on the inside of this membrane and forms the electrode at which the gas molecules of interest will react. The electrodes may be covered with an activating layer, which is responsible for the reaction.

Inside the cell are at least one other electrode and the electrolyte. Variations in the electrode and electrolyte materials, regardless of whether a polarising voltage is continuously applied, and the precise way in which the electrodes are employed in the circuit, are used to obtain specificity to different gases.

Some electrochemical sensors may use an additional chemical pre-reaction, the products of which result in the electrochemical reaction at the contact surface of electrode and electrolyte.

Usually the gas of interest is consumed by the redox reaction, and the reaction products are commonly transported through the cell to the counter electrode. 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.

The electrodes or electrolyte in electrochemical sensors may gradually be modified or consumed by reactive gases. The sensors require recalibration at suitable intervals to correct for drifts in zero and sensitivity, and ultimately require replacement. Typical lifetimes under favourable conditions can exceed 2 years.

Their response time and recovery time $t_{(90)}$ are comparatively long (typically > 30 s), especially after overload and near the end of their life. There are usually limits on low temperature and low humidity operation.

A.6.2 Common applications

Electrochemical cells are compact, require little power, and have a high sensitivity to certain gases.

Electrochemical cells are not available for detecting most hydrocarbons (for example the alkanes methane, ethane, propane, etc.).

However, 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 LFL, and oxygen up to 25 % v/v. There are also sensors available for up to 100 % v/v oxygen.

Additionally, these sensors are commonly used for measuring gas concentrations down to low parts per million levels, for example, in leak detection and personal monitoring for many specific toxic gases (as opposed to vapours), such as H_2S, CO, HCN, NH_3, PH_3, SO_2, NO, NO_2 and ethylene oxide. Although they may be specified for a particular gas, they may detect other interfering gases.

Portable equipment for the detection of flammable gases, using other sensor types described in this standard for their 0 to 100 % LFL ranges, frequently have such electrochemical toxic gas sensors and electrochemical oxygen sensors fitted in a multi-gas configuration.

A.6.3 Limitations

Temporary loss of sensitivity occurs in moving a cold sensor of this type into a warmer high humidity situation due to water condensing on the membrane, partially blocking it. This is particularly noticeable on oxygen sensors where a normal reading of just under 21 % can drop for this reason and give an alarm for a few minutes. Contamination by non-volatile liquids or adhesive solids can have a similar but permanent effect.

Dependent on the sensor, oxygen may be required for the electrochemical reaction. In such cases dissolved oxygen in the electrolyte will last for short periods, but prolonged operation in oxygen-free situations is not possible.

The electrolyte or one or more of the electrodes will usually limit the life of the sensor. The sensitivity will usually fall with time, requiring periodic recalibration or response checking.

Dependent on the type of sensor and the gas to be measured, the sensor may have a shortened life or a drop in response due to an overload of gas. This can happen particularly with oxygen sensors used in high oxygen concentrations, where a lead electrode is consumed proportionally to the oxygen exposure.

The lifetime of many sensor types is also dependent on the dose of other gases because the electrolyte will be consumed. In particular, high concentrations of carbon dioxide can result in loss of sensitivity and shorten the electrolyte life in certain oxygen sensors.

In most cases the influence of temperature on the sensitivity of the sensor is well-known and is reproducible. Therefore the equipment may have electronic temperature compensation.

Low temperature or humidity may reduce the sensitivity and increase the response time of the sensor. Prolonged operation in very low humidity may dry out the electrolyte. However, some sensors have a reservoir containing material for maintaining humidity in order to avoid this effect.

Electrolyte properties will limit the low (and in some cases the high) temperature operation, see the instruction manual.

Response time and recovery time $t_{(90)}$ are comparatively long, typically > 30 s.

A.6.4 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 sensitivity is proportional to atmospheric pressure. Other types of sensor are affected or damaged by pressure pulses: refer to the instruction manual.

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 flammable gases, such as:

- the molecular mass 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.

A.6.5 Poisoning

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

Apart from contamination as discussed above, the gas inlet of the sensor or membrane may be gradually reduced or even blocked by reaction products, for example, from hydrolysis of halogenated compounds like boron trifluoride (BF_3), silicone tetrachloride ($SiCl_4$) etc.

As mentioned, some oxygen sensors may lose their sensitivity due to high concentrations of CO_2 in the atmosphere reacting with their electrolyte.

A.7 Flame ionization detectors (FID)

A.7.1 General

The operating principle of the flame ionization detector depends upon the ionization (electrical charging) of organic compounds as they are burnt in a detector with an internal hydrogen flame. The ion cloud so formed migrates under a potential gradient of up to a few hundred volts maintained between electrodes in the combustion chamber. This results in a very low electric current, proportional to the concentration of gas/vapour in the gas stream, which is then amplified.

This type of detector has excellent linearity over a range up to several decades, from low (parts per million) concentrations up to the lower flammable limit. A flame of pure hydrogen (and air) produces a negligible number of detectable ions, giving a base current of less than 0,1 pA. This allows the measurement of mass flows of organic compounds down to 10 pg/s to 15 pg/s.

One electrode is usually the miniature flame jet itself and is negative. The positive electrode is usually cylindrical or annular, located close to and surrounding the flame.

A source of ignition (spark gap or glow plug) will be provided in the detector.

The hydrogen flow is usually controlled at only a few tens of millilitres per minute. It should not contain organic compounds and other pollutants, but can contain some amount of gases such as nitrogen, oxygen, water vapour, etc. In most cases the sample is controlled at a flow of a few millilitres per minute, its background gas does not have to be air, and it is mixed with the hydrogen just before the flame jet.

Air for the combustion, usually at a flowrate of 100 ml/min or more, is normally fed through a ring slit into the combustion chamber. If the sample is mixed with the hydrogen as above, this air should be free of organic contaminants. Otherwise, for simpler portable or transportable devices, intended for detecting low concentrations of organic gases in air, this may be a flow of the air sample itself, eliminating the need for a separate air supply.

All gas flows should be held constant at optimised levels and the temperature of the combustion chamber should be stabilised.

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.

The ionisation 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 ionised and measurable. In hydrocarbons the response is roughly proportional to total carbon.

Therefore the relative responses of different hydrocarbons expressed in mole fractions are roughly proportional to the number of carbon atoms in their molecules. However for oxygenated compounds, this relative response gets modified: C-O bonds in molecules do not produce detectable ions. The apparent number of carbon atoms needed to calculate the signal has to be reduced by half for each oxygen atom in the molecule. For instance formic acid HCOOH does not give a response (1 carbon minus ½ for each oxygen equals zero). This effect reduces the empirical response if the FID is used as total carbon analyser.

However, 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, whether the sample is added to the hydrogen or is used as the combustion gas, 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 or cause trouble with insulation, and thus reduce the detector signal.

A.7.2 Common applications

This type of sensor is used where high sensitivity, wide measuring range, small measuring uncertainty, poison resistance and fast response time are of main interest. The sensor is suitable for measuring ranges from the parts per million level up to the LFL and even above.

Almost all organic compounds, most of which are flammable, will give a signal. The notable exceptions are formaldehyde and formic acid which do not give a response.

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

A.7.3 Limitations

The principle of operation is not selective because generally all organic compounds cause a signal. If different gases are expected at the place of operation, the sensor should be calibrated for that gas to which the equipment is least sensitive. Within limits, however, relative responses are more calculable than for other measuring principles.

Apart from the few organic exceptions already mentioned, these sensors are also not suitable for the flammable inorganic gases; hydrogen, carbon monoxide, ammonia, carbon disulfide, hydrogen sulfide and hydrogen cyanide.

The sensors will also detect some organic compounds that are not flammable.

External gases, hydrogen and (usually) synthetic air for its combustion are required. However in some cases the sample itself may be used as the combustion air. The signal is critically dependent on both sample and hydrogen flow rates, and less so on the combustion air flow. Therefore pressure of the gas sample, air and flammable gas should be kept constant, but it should be noted that the flame arrestors used in the sampling line can be soiled and difficulty may be experienced in keeping the sample flow constant.

A.7.4 Interferences

Inert and rare gases, nitrogen oxides, halogens, nitrogen, oxygen, carbon dioxide, carbon tetrachloride, and water give no response.

Halogenated hydrocarbons reduce the response when the equipment is calibrated for measuring the total carbon content of the gas mixture.

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

A.7.5 Poisoning

Generally there is no poisoning effect, but if silicones or other substances that result in solid combustion products are present, they may result in a coating of the electrodes and insulation which will reduce the sensitivity and ultimately make the sensor inoperative.

A.8 Flame temperature analysers (FTA)

A.8.1 General

The operating principle of the flame temperature analyser detector depends upon the rise in temperature of a flame burning a constant flow of hydrogen (or some other gas) by flammable contaminants in the air sample supporting the flame's combustion.

Inside a small detector chamber the temperature of the flame is measured by a detector. 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 5 s can be obtained.

The burner gas (usually hydrogen) should be of constant composition. To ensure a stable zero signal, in the absence of the gas to be measured in the combustion air, all gas flows should be held constant at optimised 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 flammable gas will reduce the flame temperature; this should be detectable by the equipment. Halon at high concentrations in the presence of flammable substances may cause a misreading and may even extinguish the flame.

A.8.2 Common applications

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

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

A.8.3 Limitations

The principle of operation is not selective as the response depends only on the calorific nature of the sample. At higher concentrations the response is not linear. For range limitations refer to the instruction manual.

The sensor is not recommended for measurement in parts per million ranges.

External gas(es) are 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 needs to be provided for the burner. The signal is critically dependent on the flow rates of sample, fuel, and, where used, combustion air. Therefore, as in FID, pressure of the gas sample, air and flammable gas should be kept constant, but it should be noted that the flame arrestors used in the sampling line can be soiled and difficulty may be experienced in keeping the sample flow constant.

A.8.4 Interferences

Halogenated hydrocarbons, such as halons at high concentrations may decrease the signal by reduction of the flame temperature.

A.8.5 Poisoning

There is no known poisoning effect.

A.9 Photo ionisation detector (PID)

A.9.1 General

This detection principle is based on ionisation of gases by ultraviolet (uv) radiation from a special lamp of known wavelength, and hence photon energy, usually quoted in electron-volts eV (e.g. 10,6 eV). This lamp is at one side of a detector cell. Gas molecules present in the cell with a lower ionisation potential (IP) than the lamp's output will become ionised by the radiation, and a current will then flow between two electrodes in the cell which have an electric potential applied between them. This current is proportional to the concentration of the substance over several orders of magnitude.

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.

Substances with higher IP values than the lamp will not be detected. For instance, substances like ethane, propane, acetylene or methanol have IP's higher than the 10,6 eV value of the most common lamp. Other substances with values just below, such as ethanol and ethylene with a IP of 10,5 eV give a low response.

In principle, as the measurements are usually performed in air, all substances having an IP higher than oxygen (IP = 12,1 eV), such as hydrogen, carbon monoxide and methane, cannot be detected. There is no point in having a lamp of higher value than this.

The technique is not specific to flammable gases, and with the more common ultra violet lamps, it will not detect all flammable gases.

Ionisation potential of various substances can be found in the literature or a list may be obtained from the equipment 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 flammable compounds such as ammonia, hydrogen sulfide and carbon disulfide; and some non-flammable gases such as nitrogen dioxide, nitric oxide and trichloroethylene.

Relative responses are generally well known so that is possible to pre-program them into software. After recalibration on a standard gas, if the identity of the gas to be detected is selected, a direct readout can therefore be obtained.

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

A.9.2 Common applications

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

Although the technique is suitable for fixed operation, the equipment may be portable (hand held) or transportable type and usually will have an aspiration pump built in. In this form the technique is suitable as spot reading equipment.

This sensor is suitable for the measurement of gas concentrations from low parts per million range up to approximately 2000 parts per million. Thus it is suitable for measurements from toxic levels to low percentages of LFL.

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

A.9.3 Limitations

The measuring principle is not selective for flammable gases. It will detect all substances, whether flammable or not, which have an ionisation potential (IP) lower than the energy of the UV-lamp.

The sensor will not detect compounds having ionisation potentials higher than the lamp energy of the detector. Most sensors have a UV lamp with an energy of 10,6 eV. This is unsuitable for low alkanes and some other common flammable substances.

Alternative lamp energies may range from 8,4 eV (which will not detect many other substances), to 11,7 eV for use in air, which will permit more gases to be detected, (refer to the documentation of the equipment).

The sensor cannot detect carbon monoxide, hydrogen, or methane in air with any of these lamps.

This type of sensor is not recommended for measuring higher concentrations than about 2000 parts per million because the response is not linear. For range limitations refer to the instruction manual.

The higher energy lamps tend to have reduced lifetimes.

A.9.4 Interferences

The sensor will respond to all substances having an ionisation 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 ionisation (IP of H_2O is 12,6 eV) but may be caused by an interaction with material surrounding the electrodes.

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

Condensed material, solid material, fingermarks, etc. on the lamp or cell windows can alter the ultraviolet intensity and hence the sensitivity.

A.9.5 Poisoning

Generally there is no known poisoning effect.

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

A.10 Paramagnetic oxygen detector

A.10.1 General

Oxygen is strongly paramagnetic (attracted to a magnetic field). Nitric oxide is about half as paramagnetic. Nitrogen Dioxide is about 4 % as paramagnetic as oxygen. Other gases are two orders of magnitude less paramagnetic or very weakly diamagnetic (repelled by a magnetic field). Gases containing oxygen will tend to be drawn into a strong magnetic field with a force proportional to the oxygen fraction. NO and NO_2 will be drawn to a proportionately lesser extent and other gases have a negligible effect, making the technique effectively highly specific for oxygen in the absence of appreciable amounts of nitric oxide.

There are various techniques used to exploit this effect. Equipment of the dumb-bell type utilises 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 attraction of paramagnetic gas into the magnetic field and trying to displace the dumb-bell, is detected optically and a feedback loop electromechanically returns the dumb-bell back to balance. The feedback current required is therefore proportional to the concentration of paramagnetic gas. The signal requires compensation for pressure and temperature. The equipment is also sensitive to shock and vibration, but can be made transportable.

Equipment 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 equipment reading will usually be orientation dependent, therefore the equipment should be fixed.

Equipment based on the differential pressure (Quincke) effect transduces 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.

A.10.2 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.

A.10.3 Limitations

Dependent on the particular detection method used, the equipment 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.

A.10.4 Interference

Except for NO and NO_2, which give signals of around 50 % and 4 % respectively of the oxygen signal at equivalent concentrations, there are no significant interferences by other gases.

A.10.5 Poisoning

There is no known poisoning effect.

Annex B
(informative)

Environmental parameters

Table B.1 lists the minimum level criteria for environmental conditions within IEC 60079-29-1. For further details on test conditions and acceptance criteria, consult the referenced standard.

In all cases, the environmental conditions of the area(s) of use should be compared with the data specified by the manufacturer's instruction manual. In any case where the environmental conditions may exceed the values below or those in the instruction manual, the manufacturer should be consulted.

Table B.1 – Environmental parameters

Parameter	Based on IEC 60079-29-1	
Unpowered storage	24 h at each temperature sequentially: –25 °C +20 °C (ambient) +60 °C +20 °C (ambient)	
Temperature	Portable/Transportable	–10 °C to +40 °C
	Remote sensor	-25 °C to +55 °C
	Separate control unit	+5 °C to +55 °C
	Fixed with integral sensor	–10 °C to +55 °C
Pressure	80 kPa to 120 kPa	
Relative Humidity	20 % r.h. to 90 % r.h.	
Air speed	Up to 6 m/s	
Vibration	All units which include a sensor: 10 Hz to 30 Hz, 1,0 mm total excursion; 31 Hz to 150 Hz, 2 *g* acceleration peak Control unit used with remote sensor(s): 10 Hz to 30 Hz, 1,0 mm total excursion; 31 Hz to 100 Hz, 2 *g* acceleration peak	
Drop test	Portable:	fall height 1,0 m
	Transportable (< 5 kg):	fall height 0,3 m
	Transportable (≥ 5 kg):	fall height 0,1 m

Annex C
(informative)

Typical environmental and application check-list for flammable gas detectors (for both Group I and Group II equipment)

1. Briefly describe the application in which flammable gases are to be detected (address: sampling methods, special environments, locations)

2. If monitored points are separate from the control unit, what distances are involved?

3. List flammable gas(es) and/or vapour(s) to be detected and their approximate sample composition.

Gas or vapour component*	Concentration (units)	Special considerations

* List also chemical name if possible.

If more than one flammable gas is anticipated, indicate whether these gases or vapours will be present separately or in combination.

4. Is detection to be in normal (21 % O_2), oxygen-deficient, or oxygen-enriched atmospheres?

Estimated oxygen range of atmosphere to be sampled:

5. Required instrument measuring range(s) other than LFL (lower flammable limit):

6. Ambient temperature range in which the control unit is to be used:

____________________ °C minimum to ______________________ °C maximum

Nominal expected temperature: _______________________________ °C

7. Ambient humidity range of atmosphere to be monitored:

____________________ % RH minimum to ____________________ % RH maximum

8. Pressure range of atmosphere to be monitored:

   ______________________ minimum to __________________________ maximum

9. Velocity range of atmosphere to be monitored:

   ______________________ minimum to __________________________ maximum

10. Other pertinent conditions (presence of dust, corrosives, fumes, mists, etc.). Please state type and amount, if possible.

    ____
    ____
    ____
    ____

11. Potential desensitizing agents: state whether the atmosphere may include silicone, lead, halogenated compounds, or other materials which can affect sensor performance.

    ____
    ____
    ____

12. Classification of the location in which the control unit is to be used:

    Gas Group: __________________ Zone: _______________ Group: _____________
    Gas Group: __________________ Zone: _______________ Group: _____________

13. Additional accessories required:

    ____
    ____
    ____
    ____
    ____

Annex D
(informative)

Typical instrument maintenance record for flammable gas detectors

Manufacturer:

Model No.:

Date purchased:

Date placed in service:

Serial No.:

User ID No.:

Calibration gas:

Location:

Maintenance other than routine calibration

Date	Check one		Returned by	Serviced by	Nature of service and parts replaced
	Scheduled maintenance	Failure			

1						
	Comments:					

2						
	Comments:					

3						
	Comments:					

4						
	Comments:					

5						
	Comments:					

Calibration records

Date		Comments
1		
2		
3		
4		
5		

Annex E
(informative)

Atmospheric visibility

(applicable to open path equipment)

Attenuation in the atmosphere is caused by the scattering and absorption and the attenuation is expressed by the Beer-Bougeur-Lambert Law:

$F = F_o \exp(-ex)$

where

x is the optical path length;

F is the value of luminous flux at distance x;

F_o is the value of luminous flux at distance 0;

e is the extinction coefficient embodying both absorption and scattering.

From the definition of Meteorological Optical Range (MOR), see 3.7.5:

$F = 0{,}05\ F_o$ when x = MOR.

Hence MOR = -(1/e)ln(0,05).

From the definition of transmittance, see 3.7.13:

$T = F/F_o = \exp(-ex)$.

Thus by eliminating e from the equations:

MOR = x(ln 0,05)/(ln T).

This calculation assumes that the particle size for fog precipitation or dust is large enough compared with all significant wavelengths so that attenuation can be treated as independent of wavelength. Radiation from an incandescent source at 2 700 K as used to define MOR is maximum at about 1 micron wavelength so the estimate will be most useful for instruments working at visible and near infrared wavelengths. It will tend to underestimate the equivalent MOR for instruments working in the ultra violet and overestimate the equivalent MOR for instruments working in the mid and far infrared.

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