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INTERNATIONAL STANDARD

colour inside

Workplace atmospheres –
Part 2: Gas detectors – Selection, installation, use and maintenance of detectors for toxic gases and vapours

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INTERNATIONAL
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WORKPLACE ATMOSPHERES –

**Part 2: Gas detectors –
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of detectors for toxic gases and vapours**

FOREWORD

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International Standard IEC 62990-2 has been prepared IEC technical committee 31: Equipment for explosive atmospheres and ISO technical committee 146: Air quality, sub-committee 2: Workplace atmospheres.

It is published as a double logo standard.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
31/1566/FDIS	31/1568/RVD

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

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

A list of all parts in the IEC 62990, published under the general title *Workplace atmospheres*, can be found on the IEC website.

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

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- withdrawn,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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Toxic gas detection equipment can be used whenever there is the possibility of a hazard to life or adverse health effects caused by the accumulation of a toxic gas or vapour. Such equipment can provide a means of reducing the exposure to the hazard by detecting the presence of a toxic gas or vapour and issuing suitable audible or visual warnings. Gas detectors can also be used to initiate precautionary steps (for example, plant shutdown and evacuation).

Performance requirements for gas detection equipment for workplace atmospheres are set out in IEC 62990 series standards.

However performance capability alone cannot ensure that the use of such equipment will properly safeguard life and health where toxic gases and vapours might 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.

This document has been specifically written to cover all the functions necessary from selection to ongoing maintenance for a successful gas detection operation.

WORKPLACE ATMOSPHERES –

Part 2: Gas detectors – Selection, installation, use and maintenance of detectors for toxic gases and vapours

1 Scope

This document gives guidance on the selection, installation, use and maintenance of electrical equipment used for the measurement of toxic gases and vapours in workplace atmospheres. The primary purpose of such equipment is to ensure safety of personnel and property by providing an indication of the concentration of a toxic gas or vapour and warning of its presence.

This document is applicable to equipment whose purpose is to provide an indication, alarm or other output function to give a warning of the presence of a toxic gas or vapour in the atmosphere and in some cases to initiate automatic or manual protective actions. It is applicable to equipment in which the sensor automatically generates an electrical signal when gas is present.

For the purposes of this document, equipment includes:

a) fixed equipment;
b) transportable equipment, and
c) portable equipment.

This document is intended to cover equipment defined within IEC 62990-1, but can provide useful information for equipment not covered by that document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 62990-1, *Workplace atmospheres – Part 1: Gas detectors – Performance requirements of detectors for toxic gases*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62990-1 and the following apply.

NOTE 1 Certain definitions within IEC 62990-1 are repeated below for the convenience of the reader.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

NOTE 2 Additional definitions applicable to explosive atmospheres can be found in Chapter 426 of the International Electrotechnical Vocabulary (IEC 60050-426).

3.1
toxic gas
gas or vapour that can be harmful to human health and/or the performance of persons due to its physical or physico-chemical properties

Note 1 to entry: For the purpose of this document, the term “toxic gas” includes “toxic vapours”.

3.2
interfering gas
any gas other than the gas to be detected, including water vapour, which affects the indication

3.3
clean air
air that is free of gases or vapours to which the sensor is sensitive or which influence the performance of the sensor

3.4
zero gas
gas recommended by the manufacturer, which is free of toxic gases and interfering and contaminating substances, the purpose of which is calibration or adjustment of the equipment zero

3.5
volume fraction
quotient of the volume of a specified component and the sum of the volumes of all components of a gas mixture before mixing, all volumes referring to the pressure and the temperature of the gas mixture

Note 1 to entry: The volume fraction and volume concentration take the same value if, at the same state conditions, the sum of the component volumes before mixing and the volume of the mixture are equal. However, because the mixing of two or more gases at the same state conditions is usually accompanied by a slight contraction or, less frequently, a slight expansion, this is not generally the case.

3.6
occupational exposure limit value
OELV
limit of the time-weighted average of the concentration of a chemical agent in the air within the breathing zone of a worker in relation to a specified reference period

Note 1 to entry: The term “limit value” is often used as a synonym for “occupational exposure limit value”, but the term “occupational exposure limit value” is preferred because there is more than one limit value (e.g., biological limit value and occupational exposure limit value).

Note 2 to entry: Occupational exposure limit values (OELVs) are often set for reference periods of 8 h, but can also be set for shorter periods or concentration excursions.

[SOURCE: ISO 18158:2016, 2.1.5.4, modified (Note 2 to entry is shortened)]

3.7
exposure (by inhalation)
situation in which a chemical agent is present in air that is inhaled by a person

3.8
time weighted average concentration
TWA concentration
concentration of gas in air averaged over a reference period

3.9
fixed equipment
equipment fastened to a support, or otherwise secured in a specific location, when energized

3.10
transportable equipment
equipment not intended to be carried by a person during operation, nor intended for fixed installation

3.11
portable equipment
equipment intended to be carried by a person during its operation

Note 1 to entry: Portable equipment is battery powered and includes, but is not limited to;

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 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 carrying harness and which might or might not have a hand directed probe.

3.12
aspirated equipment
equipment that samples the atmosphere by drawing it to the sensor

Note 1 to entry: A hand operated or electric pump is often used to draw gas to the sensor.

3.13
alarm-only equipment
equipment with an alarm but not having an indication of measured value

3.14
sensing element
part of the sensor which is sensitive to the gas or vapour to be measured

3.15
sensor
assembly in which the sensing element is housed and that can also contain associated circuit components

3.16
remote sensor
sensor which is installed separately, but is connected to a gas detection control unit, gas detection transmitter, or transportable or portable equipment

3.17
gas detection transmitter
fixed gas detection equipment that provides a conditioned electronic signal or output indication to a generally accepted industry standard (such as 4 to 20 mA), 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

3.18
separate gas detection control unit
equipment intended to provide display indication, alarm functions, output contacts or alarm signal outputs or any combination when operated with gas detection transmitters(s)

3.19
alarm set point
setting of the equipment at which the measured concentration will cause the equipment to initiate an indication, alarm or other output function

3.20
fault signal
audible, visible or other type of output, different from the alarm signal, permitting, directly or indirectly, a warning or indication that the equipment is not working satisfactorily

3.21
sample line
means by which the gas being sampled is conveyed to the sensor

Note 1 to entry: Accessories such as filter or water trap are often included in the sample line.

3.22
sampling probe
separate accessory sample line which is optionally attached to the equipment

Note 1 to entry: It is usually short (for example in the order of 1 m) and rigid, although it can be telescopic. In some cases it is connected by a flexible tube to the equipment.

3.23
field calibration kit
means of presenting test gas to the equipment for the purpose of calibrating, adjusting or verifying the operation of the equipment

Note 1 to entry: The field calibration kit can be used for verifying the operation of the alarms if the concentration of the test gas is above the alarm set-point.

Note 2 to entry: A mask for calibration and test is an example of a field calibration kit.

3.24
zero indication
indication given by an equipment when exposed to zero gas in normal operating conditions

3.25
indication range
range of measured values of gas concentration over which the equipment is capable of indicating (see Figure 1)

3.26
lower limit of indication
smallest measured value within the indication range (see Figure 1)

3.27
upper limit of indication
largest measured value within the indication range (see Figure 1)

3.28
measuring range
range of measured values of gas concentration over which the accuracy of the equipment lies within specified limits (see Figure 1)

3.29
lower limit of measurement
smallest measured value within the measuring range (see Figure 1)

3.30
upper limit of measurement
largest measured value within the measuring range (see Figure 1)

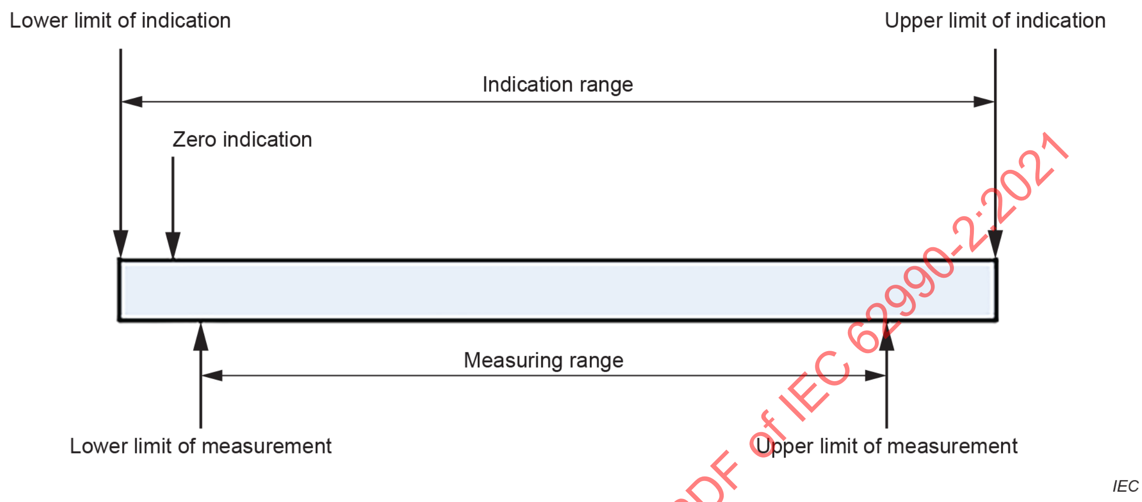

Figure 1 – Relationship between indication range and measuring range

3.31
expanded uncertainty
U
quantity defining an interval about a result of a measurement, expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

[SOURCE: ISO 18158:2016, 2.4.2.5]

3.32
zero uncertainty
quantity defining an interval about zero expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurement in clean air

Note 1 to entry: In Figure 2 the mean value of the measured values in clean air is not equal to zero to illustrate that there can be an offset due to drift. The mean value can be above or below zero.

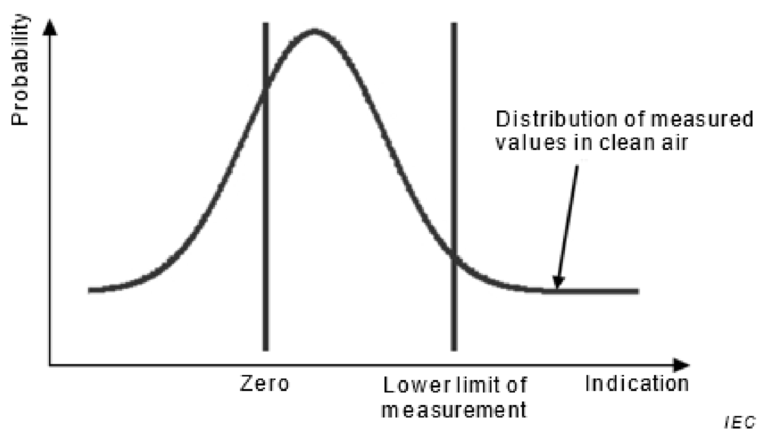

Figure 2 – Example of zero uncertainty

3.33
selectivity
degree of independence from interfering gases

3.34
averaging time
period of time for which the measuring procedure yields an averaged value

3.35
drift
variation in the equipment indication over time at any fixed gas volume fraction (including clean air) under constant ambient conditions

3.36
time of recovery
$t(x)$
time interval, with the equipment in a warmed-up condition, between the time when an instantaneous change from standard test gas to clean air is produced at the equipment inlet and the time when the indication reaches a stated percentage (x) of the initial indication

Note 1 to entry: For alarm only equipment the stated indication can be represented by the de-activation of the alarm set at a stated value.

3.37
time of response
$t(x)$
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 is produced at the equipment inlet, and the time when the indication reaches a stated percentage (x) of the final indication

Note 1 to entry: For alarm only equipment the stated indication can be represented by the activation of the alarm set at a stated value

3.38
warm-up time
time interval, with the equipment in a stated atmosphere, between the time when the equipment is switched on and the time when the indication reaches and remains within the stated tolerances

Note 1 to entry: See Figure 3.

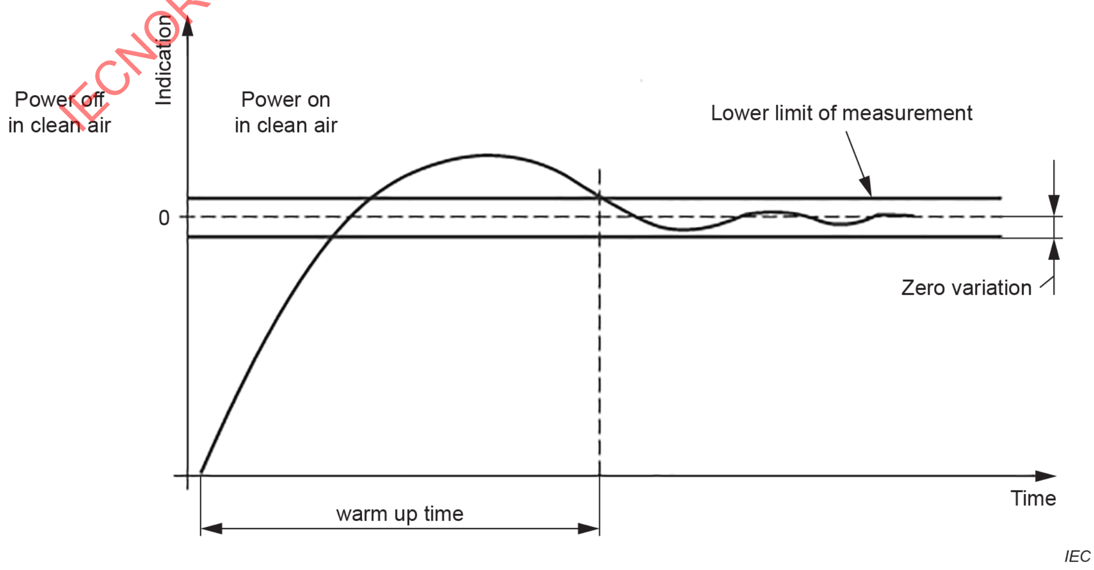

Figure 3 – Example of warm-up time in clean air

3.39
calibration
procedure which establishes the relationship between a measured value and the concentration of a test gas

Note 1 to entry: If the deviation at calibration is too high, usually an adjustment will be carried out subsequently.

3.40
adjustment
procedure carried out to minimize the deviation of the measured value from the test gas concentration

Note 1 to entry: If the equipment is adjusted to give an indication of zero in clean air, the procedure is called 'zero adjustment'.

3.41
special state
state of the equipment other than those in which monitoring of gas concentration or alarming is the intent

Note 1 to entry: Special state includes warm-up, calibration mode or fault condition.

3.42
ventilation
movement of air and its replacement with fresh air due to the effects of wind, temperature gradients, or artificial means (for example, fans or extractors)

4 Properties and detection of toxic gases and vapours

4.1 Properties and detection

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. The following properties and behaviours of gases should be taken into account, in particular when locating detectors or deciding on a sampling strategy, in order to obtain representative indications. Failure to take proper consideration of these gas properties and behaviours can lead to failure to alarm and failure to take appropriate action or false alarms and incorrect action. It can also lead to false estimates of exposure.

Toxic gases typically become harmful at low concentrations (occupational exposure limit values typically range from parts per billion (ppb) to 1 % v/v levels). At distances far from the source of toxic gas release, the relative density of such a gas mixture is not significantly different from that of air. However, close to the source, the relative density can be significantly different, although consideration should be given to influences by the thermal effect of pressurised gas.

Gases and mixtures with relative densities between 0,8 and 1,2 should generally be considered to behave like air at ambient temperatures and are therefore capable of propagating in all directions.

High pressure leaks can generate gas clouds that propagate over significant distances from the source before mixing. This can occur for sources where the gas can be of any density.

In stagnant environments low pressure leaks can build up local high concentration pockets due to insufficient passive air movement.

Spillage of liquids can result in toxic vapour clouds that can disperse over long distances and duration and can accumulate in trenches, drains, tunnels etc. This is a result of liquid and vapour flow under gravity, cooling due to evaporation, and densities greater than air. The vapour cloud tends to stay close to the ground until well mixed with air. Nevertheless, concentrations in the breathing zone can approach harmful levels.

Gases and vapours fully mix with each other by diffusion over time or if stirred (for example, by convection or mechanical ventilation). Once they have been mixed, they will remain mixed, unless a component is removed chemically or is absorbed, for instance on a charcoal filter. Additionally, in the case of vapours, the concentration can be lowered by condensation due to increased pressure or reduced temperature. Some gases can react chemically with each other on mixing, for example, nitric oxide and oxygen.

The toxic component within a gas mixture follows the characteristics of the mixture, irrespective of the physical characteristics of the toxic component in pure form. The detection of H_2S for sour gas applications should be based on consideration of the characteristics of the sour gas mixture as a whole – typically dominated by methane, i.e. a “lighter than air” mixture, irrespective of the properties of pure H_2S.

Air movement by convection, mechanical ventilation or wind can have a marked effect on gas distribution. A heat source in an enclosed space, for example, can create a circular flow where the heated gas rises, runs along the ceiling which is at a lower temperature and falls as it cools, then runs along the floor back to the heat source.

Flow patterns can become very complicated and voids might well exist in which the gas can accumulate. Consequently, each workplace scenario could be different. The use of smoke tubes, mathematical modelling or scale models placed in wind tunnels can help to optimize the location of fixed detectors.

Some gases tend to stick (adsorb) on surfaces, which leads to a decrease of their concentration in air. This behaviour can be significant, especially with low gas concentrations and for reactive gases. Adsorbed gases can desorb and produce a response even when there is no gas present in the monitored air. The adsorption/desorption properties of each gas should be considered before the measurement task is undertaken. This is particularly important where sampling probes or sample lines are used to convey the gas to the equipment. The gas flow rate, temperature, length, diameter and material from which the probe or line is made are important factors.

Hygroscopic gases can form aerosols, which could be hazardous. A detector, which is only capable of measuring gas phase concentrations, will underestimate the true hazard.

4.2 The difference between detecting gases and vapours

4.2.1 Gases

4.2.1.1 Characteristics of gases

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.

Gases can 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.

4.2.1.2 Calibration considerations

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

Where a sensor is intended for use with more than one toxic gas (or vapour), the calibration gas should be the determination of worst case sensitivity combined with selected alarm threshold level. If more than one sensor is necessary to monitor multiple gases (or vapours), each sensor needs to be individually calibrated with the intended gas (or vapour) to be detected. Cross-sensitivity needs to be considered and fully understood.

4.2.1.3 Propagation and sampling considerations

Even when a pure gas is lighter or heavier by density than air, this is not a reliable means of determining propagation of a gas cloud.

The density of the gas to be detected should be taken into consideration when using sampling and diffusion equipment and when installing fixed detection equipment.

4.2.2 Vapours

4.2.2.1 Characteristics of vapours

Substances, where the liquid or solid can coexist with their gaseous state at normal or slightly abnormal temperatures and pressures are considered to be vapours. Vapours behave differently than gases and can be more difficult to detect accurately.

Where a liquid is present, the rate of evaporation will increase with temperature. Similarly, the maximum volume fraction of the vapour that can be achieved in a closed system (saturated vapour) will increase with temperature. This is dependent on the temperature and pressure and is 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 will be less than 100 % volume fraction.

The actual amount of vapour will be less than the amounts predicted above if fresh 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.

Toxic vapours can be present when the vapour is well below a flammable level.

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 vapour 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 will therefore change.

4.2.2.2 Calibration considerations

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.

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.

4.2.2.3 Propagation and sampling considerations

There are toxic vapours that are lighter than air.

All other vapours are denser than air. Most are considerably denser 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 toxic vapours in relatively undisturbed atmospheres, some tests need to 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 Lower Flammable Limit (LFL) but still presenting major toxicity problems.

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.

Major problems also arise in vapour testing due to the possible condensation of the sample itself in the detector or its accessories. Gas detection equipment 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 the equipment or its sample line gets contaminated by condensed vapour because it was too cold, or worse still if it gets contaminated by drawing up the toxic liquid, spurious, and possibly dangerously misleading readings will occur until such contamination is totally removed.

4.2.2.4 Toxicity and other considerations

Some toxic vapours found in industry are flammable at much higher concentrations than the measuring range of toxic gas detection equipment. Where high concentrations of vapours can occur additional precautions can be required. IEC 60079-29-2 provides guidance on the hazards and detection of flammable vapours.

NOTE For example, 5 % LFL of n-Hexane is 500 ppm which is also the TLV of n-Hexane.

4.3 Effects of water vapour on detection

Water vapour can cause problems for cold equipment and sampling equipment that is suddenly exposed to a hotter and humid atmosphere. Examples of this situation are leaving a cold store and entering a normal atmosphere or leaving an air-conditioned environment and entering a humid atmosphere. A fall in temperature or increase in pressure can also cause condensation of water vapour on the sensor inlet or sample line.

Water can condense in or on a sensor or sampling equipment causing a temporary loss of sensitivity or other effect (for example, increase in response time), until the equipment warms up and the water evaporates. For example, a film of water condensed onto the cold sensor membrane of an electrochemical sensor can cause temporary inhibition of the measurement. The sensitivity can then recover slowly until the sensor reaches ambient temperature and the film evaporates. During this period, the performance of the equipment can be impaired and the equipment might not be able to give an alarm when the gas concentration exceeds the alarm set point.

A water film on a sensor can absorb components (for example, chlorine, hydrogen chloride and phosgene) that will therefore not be detected and will subsequently be detected as the water film evaporates.

Sudden changes in humidity, either increasing or decreasing, can cause transient deviations in the indication of equipment. Equipment can be fitted with a means to detect and compensate the sensor indication for changes in humidity.

The indication of equipment depends on the humidity for most measuring principles. Any effect on the zero indication or sensitivity to the toxic gas can depend on various factors, particularly the measurement gas, type of sensor and exposure period to the humidity level.

4.4 Effects of temperature and pressure on detection

Small environmental changes can modify the composition of the atmosphere significantly. For example, where a liquid is present, the rate of evaporation of liquid will increase with temperature, which will significantly increase the toxic vapour concentration. Also, a decrease in pressure will increase toxic vapour concentration. The rise or fall in temperature can result in vapours condensing as fog inside the equipment. Temperature and humidity can affect sensor response to concentration. Equipment can be fitted with a means to detect and compensate the sensor indication for changes in temperature and pressure.

4.5 Effects of corrosion on detection

Some gases or vapours can cause corrosion or other deterioration to certain types of sensors. Some types of sensors have specific lifetimes in the presence of such substances. This deterioration causes sensitivity to change over time and is the major reason for requiring frequent response checking (see 9.1).

4.6 Detection by oxygen deficiency measurement

Oxygen deficiency measurement should never be used to detect toxic gases. The reduction in oxygen concentration by harmful levels of toxic gases is negligible when compared to other effects on oxygen measurement, for example, variation of ambient temperature.

An oxygen deficient atmosphere can, for example, be created by several different sources of carbon dioxide. Such sources can be leakage causing displacement of the air, combustion consuming oxygen or aerobic bacterial or chemical action. These all result in different reductions in oxygen concentrations for a given carbon dioxide concentration. The occupational exposure limit value for carbon dioxide is 0,5 % (v/v) which corresponds to a reduction of the oxygen concentration of only 0,1 % (v/v) when the air is displaced by carbon dioxide, which is less than the variation caused by other effects on oxygen measurement, for example, temperature or humidity changes.

Similarly, this situation pertains to toxic gases, for example at the Immediately Dangerous to Life or Health (IDLH) level for toluene the concentration is 500 parts per million (ppm) which will have no noticeable effect on the measurement of the oxygen level.

5 Measurement tasks

5.1 General

There are an extensive number of workplace conditions where a wide range of toxic gases can be present. An individual process can involve a number of different conditions and job functions, each of which can result in different exposure conditions. Distance from an emission source and physical parameters (release rate, environmental conditions, ventilation) can also have a significant influence on exposure. Rapid fluctuations in concentration or large variations over small distances are common, therefore the location, timing and duration of measurement are of great importance. The time of response (see 3.37) and time of recovery (see 3.36) should be considered to ensure they are sufficiently small to detect rapid fluctuations where this is important.

Many types of equipment are fitted with visual and audible alarms to warn the user of high concentrations of toxic gases. Workplace conditions vary and there are also widely differing light and noise levels in the working environment. It is important to check that the alarm indicators can be seen and/or heard in the actual conditions.

The equipment will only detect gas in the location where the sensor or the sampling probe is positioned. A toxic gas atmosphere can build up at a distance from the detection point. A sufficient number of detection points should be established around the intended area of work to minimize the likelihood of exposure. Personnel risks can be mitigated further by portable or personnel monitoring.

The readings are only valid for the time they are taken as circumstances can change. Frequent readings are recommended. Otherwise, continuous monitoring devices can be used to provide alarms of excessive concentrations or to provide time-integrative values for comparison to time-integrated limit values.

A sensor for a specific toxic gas will in general not be able to detect other toxic gases with a specified accuracy. Suitable equipment should be used for all toxic gases that could be present.

Two basic measurement tasks can be identified where gas detection equipment for toxic gases are used:

– general gas detection, for example, safety warning, leak detection; and
– exposure measurement according to local regulations.

5.2 Exposure measurement (health monitoring)

A workplace monitoring strategy involves various measurement and calculation procedures. The following paragraphs give a brief outline of the general requirements.

The general requirements apply to all measurement procedures, irrespective of the physical form of the chemical agent (gas, vapour, airborne particles) and irrespective of the measurement method used. General requirements are applicable to measurement procedures with separate sampling and analysis stages and to gas detection equipment for toxic gases. The performance requirements include unambiguity, selectivity and expanded uncertainty for minimum specified measuring ranges and averaging times.

NOTE 1 For gas detection equipment for toxic gases, the averaging time is related to the internal electrical time constant of the equipment and the time constant of the sensor. For other procedures, it is normally equal to the sampling time.

NOTE 2 Different countries have different requirements and could use different values for describing safe levels of potentially toxic substances. GESTIS [1][1] is a collection of publicly available databases on hazardous substances.

Exposure measurement includes, but is not limited to, the following measurement tasks:

a) Screening measurements of time weighted average concentration.

   Used to obtain relatively crude quantitative information on exposure levels. Such information is used to identify potential health hazards, and to estimate the risk to health based on the likely severity of harm and the probability of its occurrence. These measurements can also determine if the exposure is significantly below or significantly above the occupational exposure limit value.

b) Screening measurements of variation of concentration in time and/or space.

   Used to:

   1) provide information on the likely pattern of the concentration of chemical agents in the air;
   2) identify locations and periods of elevated exposure;
   3) provide information on the location and intensity of emission sources; and
   4) estimate the effectiveness of ventilation and/or other technical measures.

c) Measurements for comparison with occupational exposure limit values and periodic measurements.

Measurements for comparison with occupational exposure limit values are used to obtain results of known uncertainty for the average concentration of a chemical agent in the air in a worker's breathing zone. Gas detection equipment is not normally used for monitoring of compliance with occupational exposure limit values because limit values are typically given as long-term averages. In the majority of cases, the method used would be sampling and analytical methods. Gas detection equipment is frequently used to obtain indications for whether sampling and analytical methods are required. Periodic measurements are used to determine whether exposure conditions have changed since the measurements for comparison with occupational exposure limit values were performed, or whether control measures remain effective.

5.3 General gas detection (safety monitoring)

General gas detection includes but is not limited to the following measurement tasks:

– providing visual and audible alarms to warn personnel of potentially harmful toxic gas concentrations (such alarms can be derived from instantaneous or time weighted average measured values);
– area monitoring to provide continuous information on the concentration of toxic substances over a site;
– measurements to monitor the effectiveness of protection systems, for example, extraction systems;
– spot reading measurements, for example, to obtain a gas free work permit; and
– leak detection in industrial and commercial environments.

Toxic gas detection equipment can also provide alarm output signals that can be used to initiate subsequent actions such as operation of a ventilation system, shutdown of processes or safe evacuation of the premises.

The following actions should be taken when using portable equipment to monitor a site during maintenance activities:

[1] Numbers in square brackets refer to the bibliography.

a) the gas detection equipment should be checked with clean air and a known concentration of the toxic gas just prior to use;
b) initial measurements should be taken to confirm the absence of the toxic gas throughout the work area;
c) continuous monitoring should be used to confirm the continued absence of the toxic gas; and
d) adequate operational procedures should be in place which identify the actions to be taken when toxic gas is detected.

Any equipment (for example, vessels, piping, ducting) can still contain toxic components. If maintenance work is required on any equipment, this shall be declared free of toxic components (for example by purging or sweeping). Operational procedures can be required to measure toxic gas remaining in equipment.

Actions a), b) and c) should be conducted by competent trained personnel authorized by the organization.

6 Selection of equipment

6.1 General

IEC 62990-1 defines Type HM (Health Monitoring) equipment and Type SM (Safety Monitoring) equipment. The performance requirements of IEC 62990-1 are intended to apply under environmental conditions present at the workplace. However, because a wide range of environmental conditions are encountered in practice, IEC 62990-1 specifies requirements that shall be fulfilled by measuring procedures when tested under prescribed laboratory conditions.

Important information on the performance characteristics of equipment can be obtained from various sources. These sources include the following:

– equipment instruction manual;
– equipment manufacturers and suppliers;
– published commercial technical information;
– technical and research publications;
– users' groups; and
– test reports.

The selection of equipment for toxic gases and vapours in workplace atmospheres will depend on many factors. These factors include:

a) the measurement task (see Clause 5);
b) the toxic gas(es) which the equipment is required to detect;
c) the measuring range and indication range (see 6.3);
d) the type of equipment: fixed, transportable, or portable (see Clauses 7 and 8);
e) the limits of operation and the sensitivity to environmental change (see 6.5);
f) electromagnetic environment;
g) requirements for functional safety, if applicable;
h) robustness and shock-resistance;
i) whether combustible gases or oxygen are also to be detected;
j) remote sampling (see 7.4);
k) self-test and self-diagnostic capabilities;
l) visual and/or audible alarm;

m) use in areas where there is a likelihood of explosive atmospheres (see 6.2);
n) selectivity to the target gases and sensitivity to interfering gases (see 6.4);
o) operating principle and characteristics of the sensor or instrumental technique (see Annex A);
p) time of response, time of recovery and time to alarm (see 6.7 and 6.8);
q) warm-up time;
r) long-term stability (see 8.3.2);
s) mains and/or battery powered;
t) operating time for battery powered equipment;
u) data logging facilities (see 6.9);
v) frequency of functional checks (see 8.2.13);
w) frequency of maintenance and calibration (see Clause 8)
x) fitness for purpose, for example, size, weight and durability
y) training requirements for the reliable operation, maintenance and calibration (see Clause 10); and
z) total cost of purchase and operation including calibration and maintenance.

6.2 Performance and electrical tests

The selection of toxic gas detection equipment is based on three independent categories:

a) assessment of the performance of the equipment to ensure it is suitable for the detection of those gases and measuring ranges it is designed for;
b) suitability of the equipment for use in explosive atmospheres to prevent the ignition of the explosive atmospheres by the equipment itself, if applicable; and
c) electrical safety.

The selection criteria for item a) are covered by this document. Items b) and c) are not covered by this document and are subject to local regulation. The equipment should be evaluated in accordance with IEC 62990-1 and the results considered for the intended application.

6.3 Indication range, measuring range and uncertainty of measurement

6.3.1 General

The measuring range is defined as the range within which the measured values meet the performance requirements in IEC 62990-1. The measuring range is not necessarily identical with the indication range of the measuring equipment (see Figure 4). This implies that the equipment could indicate values that do not meet these performance requirements. The equipment should therefore only be used over the measuring range for which the performance requirements are met.

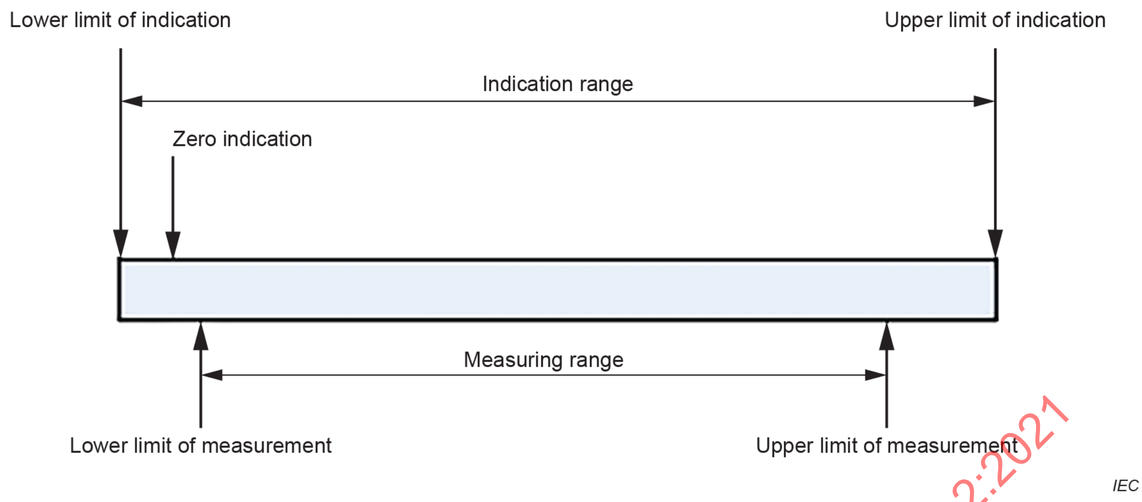

Figure 4 – Relationship between indication range and measuring range

6.3.2 Type HM (Health Monitoring) equipment

The performance requirements outlined in IEC 62990-1 are specifically for equipment used for the detection of toxic gases and vapours intended for exposure measurement. This includes requirements for the lower and upper limits of measurement and requirements for the uncertainty of measurement expressed as the relative expanded uncertainty.

Values below the lower limit of measurement are not necessarily an indication that gas is present. The calculation of the lower limit of measurement is described in IEC 62990-1.

IEC 62990-1 includes a procedure for determining a relative expanded uncertainty for Type HM equipment.

6.3.3 Type SM (Safety Monitoring) equipment

IEC 62990-1 Type SM equipment details the performance requirements for general gas detection equipment (for example, for safety warning and leak detection). The upper limit and lower limit of measurement is defined by the manufacturer. In general, the performance requirements for Type HM equipment are more stringent than those for Type SM equipment.

Open path (line of sight) systems have special requirements, limitations and characteristics that are not included within the scope of this document; and therefore, these systems need to be separately evaluated for proper application. Despite these limitations, there are applications where these systems can provide effective detection capabilities (for example, within process units of high pressure sour gas facilities), and therefore should be considered for use as a primary method of safety monitoring where appropriate. In other cases, these systems should be used as a secondary method of safety monitoring to that of point detection. Such systems usually employ an infra-red technique, where the emitter and sensor are installed at opposite ends of a 'line of sight' path traversing an area. A mirror can be used on one side of the area so that the emitter and sensor can be adjacent on the other side, and other configurations are possible.

6.4 Selectivity requirements

The gas detection equipment shall be sensitive to each of the gases that it is required to detect and 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.

Many types of equipment are not selective to a specific gas. The presence of other gases can influence the measured value by decreasing or increasing it. A decrease should be avoided when the interfering gases are likely to occur. A significantly higher measured value is also not desirable but can be acceptable in some cases. IEC 62990-1 requires that the manufacturer of the equipment indicate in the instruction manual known interfering gases likely to affect the measurement. This information can be helpful when selecting the equipment. However, there can be additional interfering gases that are not described by the manufacturer. The selectivity of the equipment can be enhanced by using selective filters where available.

Selectivity requirements can vary from case to case, depending on what is known in advance about the air composition:

a) If the air composition is not fully known in advance, then the equipment should have a high selectivity taking into account the likely interfering gases. If there are doubts about the validity of the measured values then an additional, higher selectivity analytical technique should be used to verify the measured values from the gas detection equipment for toxic gases and/or to identify the interfering gases. This information should be used to decide whether the equipment can be used.
b) If the composition of the atmosphere is qualitatively known prior to the measurement and there is no known interfering gas for the equipment, then the selectivity requirement will be low.

6.5 The influence of environmental conditions

Environmental conditions in workplaces vary widely. In general, changes in environmental conditions, for example, temperature, pressure, relative humidity and air velocity, influence the measurement.

The ranges of environmental conditions where the equipment complies with the performance requirements of IEC 62990-1 are specified in the instruction manual. The manual can also specify extended ranges of environmental conditions where the equipment can be used but will not comply with these performance requirements.

It should be noted that the ranges of environmental conditions in the instruction manual are specified for constant or slowly changing conditions. Sudden changes in environmental conditions could cause transient responses. For example, transferring portable equipment from a cold storage area to much warmer conditions could cause significant deviations in measured values until the equipment stabilises. If sudden changes in humidity can cause transient effects, then IEC 62990-1 requires that these are described in the instruction manual.

Equipment mounted on machinery or exposed to similar levels of vibration should be designed to withstand such vibration or provided with suitable vibration isolation mountings.

Those parts of the gas detection equipment that are located in, or can be taken into, an explosive atmosphere should comply with the relevant explosion protection standards (see IEC 60079-0).

Ensure the minimum oxygen concentration for correct functioning of equipment in order to attain the detection and measurement of toxic gases and vapours.

6.6 The influence of electromagnetic interference

Some types of toxic gas detection equipment are susceptible to external radio frequency interference which can cause 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.

Although IEC 62990-1 requires equipment to conform to Electromagnetic Compatibility (EMC) requirements, certain work tasks can be prone to higher levels of interference in which case users should consider locating the equipment away from the work task for example by using an aspirated sampling system.

6.7 Time of response and time of recovery

The times of response *t*(50) and *t*(90) are measured as the times to reach 50 % and 90 % of the final indication for an increase in concentration. Figure 5 presents a theoretical view of the *t*(90) but in practical situations the measured *t*(90) can depend upon the concentration. Similarly, the times of recovery *t*(50) and *t*(10) are the times to reach 50 % and 10 % of the initial indication for a decrease in concentration. The times of response and times of recovery are specified in the instruction manual and should be no greater than the maximum values specified in IEC 62990-1.

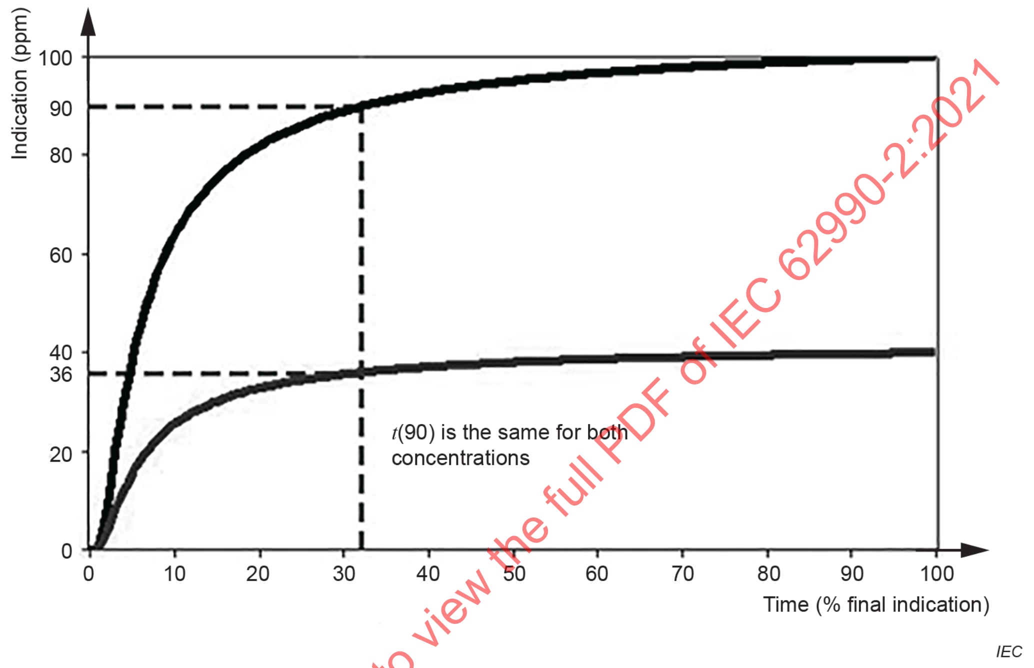

Figure 5 – Gas response curves for test gas volume fractions of 40 ppm and 100 ppm

For some critical applications for example, warning of acute health hazards, the response time should be as short as possible.

Recovery times to *t*(10) are often much longer than response times *t*(90), for example due to gas adsorbed on the surfaces of materials at or near the gas inlet of the equipment or from sample lines or sampling probes.

The addition of a sample line or sampling probe will cause an additional delay. A maximum delay of 3 s per metre length of sample line or sampling probe is allowed by IEC 62990-1.

Special designs of probes, for example, flotation devices, water traps, can create a dead space that can increase the response time. Appropriate information can be found in the instruction manual.

Within the measuring range, the time of response is generally independent of the gas concentration, as shown in Figure 5. However, for gases that adsorb strongly on the sensor and sample lines, the time of response can increase significantly at low concentrations. It is recommended to use sample tubing which minimizes the sorption of gases. Thin films of water or contamination on surfaces can greatly increase the time of response, especially for water soluble gases, for example, ammonia, chlorine.

Due to partial blockage of filters the response time specified by the equipment manufacturer can increase during use. Care should be taken in selecting equipment for dusty or high airflow environments as this effect can be significant. Periodic testing and maintenance is required to assure the specified level of performance (see Clause 9).

6.8 Time to alarm

The time to alarm is the time taken to activate the alarm following a step change from clean air to test gas. The time to alarm is not independent of the gas concentration for a given alarm set point as shown in Figure 6.

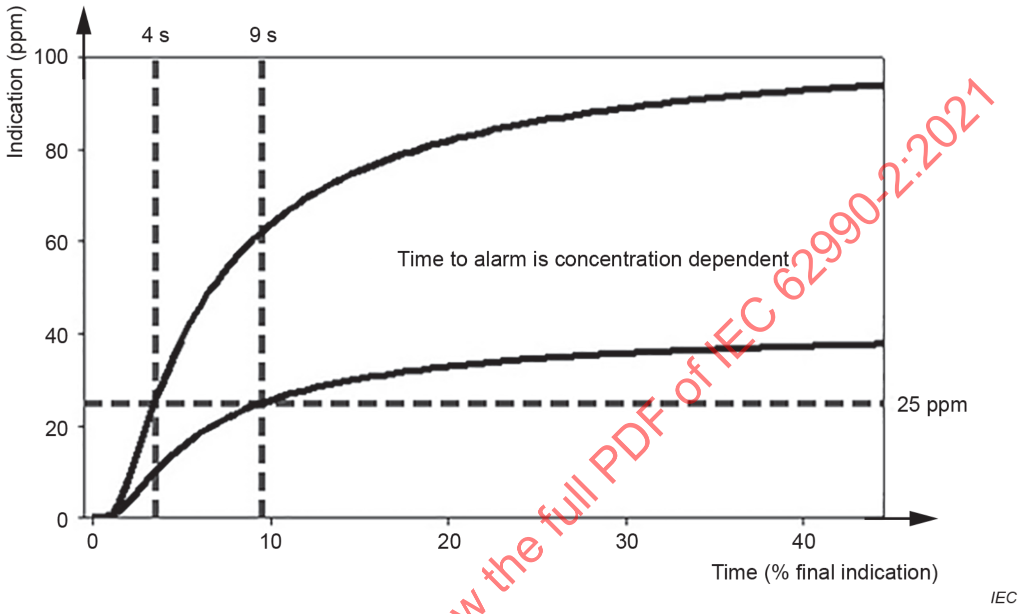

Figure 6 – Time to alarm at 25 ppm set point for test gas volume fractions of 40 ppm and 100 ppm

The following factors influence the time to alarm:

a) alarm set point and gas concentration;
b) delay time of the sampling system, if any;
c) response time of the sensor;
d) signal processing algorithms;
e) transmission times between system components; and
f) delay time of alarm devices and switching outputs.

6.9 Data logging

A data logger can assist in collecting large data sets to be used to provide information on the pattern of exposure such as:

– personal exposures for comparison with occupational exposure limit values, either short-term or long-term;
– exposure patterns during the working shift, to show the maximum concentration and time of exposure peaks;
– variations of concentration in time and/or space to provide information on the pattern of exposure and to identify locations and work activities that give rise to increased exposure.

The following factors should be considered when operating the data logger:

a) the frequency of recording and the size of the memory array

In most electronic data loggers, the frequency of recording is adjustable. The maximum practical frequency is limited by the time constant of the sensor and electronic system and the minimum is related to the measurement task and the rate of concentration changes.

The time period over which data is recorded is related to the frequency of measurement and the memory size. In most equipment, the size of the memory array is usually fixed and increasing the frequency of measurement will reduce the time period over which the measured values are recorded. Care should be taken to set the sampling frequency to a value, at which the available memory will be sufficient for the required duration of recording.

The mode of operation of the data logger should be known to ensure that no data is lost, for example by over-writing.

b) recording of measured values

Recorded values can be:

1) individual consecutive values;
2) individual values but only one out of 'n' values recorded;
3) individual values that are rounded up or down;
4) the average of a number of values; or
5) maximum or minimum values.

c) recording of other data

A variety of information relating to the operation of the equipment can also be recorded, for example, alarm status, values above a threshold, faults, calibration information, battery status, location.

d) averaging routines

Time Weighted Average (TWA) concentration values can be determined with respect to the period of measurement or to the reference period of the occupational exposure limit value, usually 15 min Short Term Exposure Limit (STEL) or 8 h (TWA). Typically, the moving average of the measured values over the reference period is calculated.

In cases where data logger information is transferred and recorded on computer, the appropriate identification data (for example, date, time, location, equipment type, serial number) should be recorded and transferred to the data file.

6.10 Instruction manual

Each gas detection equipment or group of equipment is provided with an instruction manual. The manual should be available in a language the user can understand. IEC 62990-1 requires that it contains complete, clear, and accurate instructions for safe installation, use and maintenance of the equipment.

7 Design and installation of fixed toxic gas detection equipment

7.1 General

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

a) safe evacuation of premises;
b) appropriate fire-fighting and other emergency procedures;
c) prevention, mitigation or elimination of hazard; and
d) shutdown of process or plant;
e) modifying ventilation.

The consequences to the safety of personnel, and the economic effects of potential damage, following an undetected release should be of major concern. Therefore, functional and system integrity requirements should be defined and considered from the initial system design stage and throughout the life cycle of the system.

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

Gas detection equipment can be designed to produce any or all of the following:

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

Each installation should be considered in its own right, in consultation with the manufacturer and safety authorities, evaluation of the environmental conditions in the area to be monitored and in compliance with any mandatory local safety regulations.

7.2 Basic considerations for the installation of fixed systems

If the equipment or any auxiliary components are installed in an explosive atmosphere, they should be suitable for the area in which they are installed and marked accordingly.

The fact that equipment is fixed permits the equipment to be energized ultimately from mains power. Battery back-up systems can be used when detection equipment is intended to remain functional during site power failures.

An increased efficiency of ventilation usually reduces the extent and/or rate of build-up of a toxic atmosphere. Obstacles which impede the ventilation can increase or decrease the extent and/or rate of build-up of a toxic atmosphere.

Two main types of fixed systems are commonly used.

a) Systems where sensors are positioned in the location where toxic gas can accumulate

   These systems are the most suitable for the majority of industrial applications. A system 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 toxic gases can accidentally accumulate. It 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.

   Remote sensors and gas detection transmitters should be connected to their associated control unit according to the local requirements for installation of electrical equipment. The sensors or transmitters and any other parts of the system which are located in or connected to equipment in an explosive atmosphere, should incorporate an explosion protection technique.

   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 electrical safety certification.

b) Systems which utilize sampling equipment to facilitate positioning the sensors away from where toxic gas can accumulate

   The main advantage is that they can permit all of the electrical parts of the equipment to be located outside the area of concern, with only tubes, filters, and other components, inside the area. Where a system uses sequential sampling, 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 toxic 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 toxic gas 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.

7.3 Location of detection points

7.3.1 General

IMPORTANT – The principal objective is that sensors and sampling points should be placed such that gas accumulations are detected before they create a significant hazard.

Sensors and sampling points should be located in positions determined by a competent person conducting a hazard analysis in consultation with relevant experts of the process system, gas dispersion, equipment utilised and regulatory requirements.

This determination should consider:

a) the combination of sources of release with propagation effects (Clause 7);
b) the available time for detection,
c) whether the sources of release can be inside or outside confining structures, buildings etc.;
d) what can happen at access points such as doorways, windows, tunnels, trenches etc.;
e) local environmental conditions;
f) occupational health and safety; and
g) 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.

7.3.2 General site considerations

Where it is necessary only to detect the escape of gas from within a given area, then sensors or sample points can be placed at intervals around the perimeter of the site, ensuring first the concentration at those places are in accordance with the detection objectives and next that the sensor response time is still relevant. However, such an arrangement might 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, along the most probable release direction or to establish a perimeter around a probable leak location. To avoid nuisance alarms, detection points should generally not be located immediately adjacent to equipment which can produce inconsequential minor leakage in normal operation. In general, on open sites minor leaks can be dispersed without causing a hazardous accumulation.

Sensors should also be located in all areas where hazardous accumulations of gas can occur or, when relevant, in the occupied area. 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 can accumulate in overhead cavities.

The leakage release pressure can reduce gas temperature and should be taken into consideration as it can impact the density of the gas with respect to air.

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 or build-up speed of a toxic atmosphere. The prediction can be improved by:

a) the application of generally accepted empirical rules developed by experts, based on their past experience;
b) 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; and
c) numerical simulation of gas dispersion. When a numerical model is used, this model should be able to take into account relevant physical phenomena including release geometry, nature of liquid and/or vapour phase, evaporation, thermal effects, and influence of obstacles.

Several approaches could be used for dispersion modelling, from the simplest Gaussian model to the more detailed Computational Fluid Dynamics (CFD) approach. The Gaussian approach is very simple and fast, and it can be used to evaluate many scenarios rapidly. However, such an approach does not consider the local geometry nor the specific density of the gas. Intermediate integral models enable physical phenomena such as density effects to be taken into account. Such an approach is not relevant to model the dynamic process and, consequently, should be used with care when the objective is to determine the duration of establishment of clouds. The CFD approach, however, enables consideration of all the geometrical elements and the different physical phenomena as density effects or turbulence. CFD models should be used by an expert user and the models require computation time. CFD models are also relevant in predicting dynamic dispersion with unsteady state approaches.

Modelling can be used to provide auditable assurance that a toxic gas detection layout meets a facility’s criteria for volumetric coverage with optimised numbers and locations of detector. This technique is particularly appropriate for process units containing large areas with toxic hazards and areas where a cloud can accumulate.

In general, sensors should be sited above the level of ventilation openings and close to the ceiling for the detection of gases lighter than air, and below the ventilation openings and close to the floor 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 should be sited adjacent to the ventilation openings. These sensors should be in addition to any required for the detection of releases within the building or enclosure.

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

7.3.3 Site conditions

In the case of outdoor sites and open structures, the dispersion of gas following a release can 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 can 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 detection equipment in a major plant, the use of mathematical models of gas dispersion, or of scaled wind tunnel tests, can be appropriate at the design stage.

Local thermal effects can be significant in controlling air flow patterns and can, therefore, influence the dispersion of gas. For example, large thermal gradients can 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.

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.

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. Layers of lighter than air and heavier than air gases can be disturbed by opening a door to or moving through an enclosed area.

If the release takes the form of a momentum jet, this behaviour can 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 can 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 can extend from the floor to a position above the level of the source of release. The potential of a gas jet to follow curved surfaces due to the Coandă effect should be considered.

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

Ventilation air flows are caused naturally 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 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 an unventilated building or enclosure. 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 can 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 can extend below, as well as above, the level of the source of release.

NOTE 1 Further information on ventilation is given in IEC 60079-10-1.

NOTE 2 Further information on gas dispersion is given in Cleaver et al. 1994 [2].

Ventilation air flows set up by mechanical means can be high (for example greater than 12 volume changes per hour).

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

NOTE 3 In case of very high gas concentrations (for example, above 8-hour TWA), or in the area above a toxic liquid with low vapour pressure, an increased ventilation can lead to an increased volume of the toxic 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 can accumulate. Therefore, sensors or sampling points should be installed in these spaces.

NOTE 4 Smoke tubes can assist in identifying the air movement within an enclosure and the presence of any dead spaces where gas/air mixture might 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. To avoid false alarms, the alarm setting should consider the sensor accuracy and zero drift. Additionally, the effects of increased airflow on filter contamination and effective lifetime shall be considered in product selection and routine maintenance.

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 can occur in ducting arrangements. If this happens, additional shrouding of the sensor can help. Therefore, sensors or sampling points should be installed in these spaces.

7.3.4 Environmental conditions

7.3.4.1 General

Fixed equipment, or more particularly their sensors, can 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. Acceptability is typically based on the selection of equipment with suitable environmental ratings. Additional maintenance such as cleaning a filter or lens can be necessary for the gas detection equipment to ensure proper operation after water and/or dust exposure.

7.3.4.2 Adverse weather conditions

Sensors 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 can cause drift of the zero reading. If using the manufacturer's normal calibration equipment outside the manufacturer's specified range of wind speeds the manufacturer should be consulted.

Great care should be taken in the location of sensors in exposed sites, and adequate weather protection measures should be provided for the sensor. Steam, driving rain, snow, ice and dust, etc. can also adversely affect sensors. Certain materials, although otherwise suitable for sample lines or weather guards, can deteriorate from sunlight or other environmental conditions. If additional accessories such as weather guards are required, the effect on the sensor's response time should be considered.

Sensors located in buildings or enclosures are generally not exposed to adverse weather conditions. However, sensors placed in or close to active ventilation openings can experience similar problems associated with high winds.

7.3.4.3 Excessive ambient temperatures

All sensors, sampling points, and 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 can be operating outside the temperature range specified by the manufacturer, and detection errors and reduced sensor life can occur. Care should be taken to ensure that equipment is selected such that its specifications take into account the environmental extremes to which it can be subjected.

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

In general, the positioning of gas detection equipment 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. IEC 62990-1 requires the temperature range of equipment be specified in the user manual. Consideration of extended temperature performance of equipment should be made during equipment selection in consultation with the equipment manufacturer.

7.3.4.4 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.

7.3.4.5 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, and hydrogen sulphide). 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.

7.3.4.6 Mechanical protection

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

7.3.4.7 Electromagnetic immunity

Appropriate precautions 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.

Reference should also be made to applicable national regulations regarding electromagnetic compatibility.

7.3.4.8 Pressure washing

The practice of washing plant using high pressure hoses can cause severe degradation of gas sensors and contaminate sample 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. Follow the manufacturer's maintenance procedures indicated for such conditions.

7.3.4.9 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, or 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 can require regular cleaning or similar maintenance. Sample extraction and special filtration can be required in extreme cases.

Paint overspray and deliberate painting can drastically deteriorate the performance of sensors or obstruct sampling equipment and should be avoided. Maintenance personnel should be trained to protect or avoid gas detection equipment during painting processes.

Care should be taken to avoid water condensation on diffusion screens and in sample line(s). High humidity conditions can require heating of critical parts or deliberately removing condensed water in traps, condensing 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. 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.

7.4 Access for calibration and maintenance

Sensors and sample points should be readily accessible to permit regular calibration, maintenance and electrical safety inspection. It should be possible to access and fit all accessories or test equipment needed for these operations at the detection point.

Where the sensor or sampling point location makes this difficult (for example, where it is high and over machinery), one of the following options should be used:

a) Providing temporary access to the sensor or sampling point
b) A system of lowering the sensor or sampling point on a pulley system or swinging arm to gain access can be practicable. Obviously, the cabling or sample tubing needs to be flexible or pivoted to permit this arrangement. The arrangement should preferably permit the original sensor orientation to be preserved for calibration.
c) Extended calibration gas sample tubing and signal cable to ground level.

7.5 Additional considerations for sample lines

Sample 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 might 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. Composition of the line selected shall be compatible with the gas being sampled, where minimum sorption of the gas will occur.

Filters can 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 sample line is kept clean internally. Additional devices are required for this purpose where mists can be sampled. Frequently additional filtration is provided at the sensor equipment.

Filters will increase the response time. The increase of response time is dependent on the porosity of the filter.

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 sample 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 sample line or toxic gas out of the sample line.

Where water condensation can occur, it can block the sample line. Water traps might be needed at any low spots along the sample line length. This is particularly the case if the line runs through areas that can be cooler than the sampling point (for example, air-conditioned areas in hot humid climates). Alternatively, the line can be heated, as below.

Consideration should also be given to the effects of condensation occurring with high flash point liquids on sampling systems, as this will reduce the concentration in the sample and hence the readings. 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 sample line can be necessary. In explosive atmospheres if this heating system is electrical it shall comply with the relevant regulations and standards. Steam or hot water trace heating can be an option.

7.6 Summary of considerations for the location of sensors or sampling points

The rationale for the selection of location of sensors should be formally recorded in the dossier.

Reference can be made to IEC 60079-29-2.

The following is a basic check list, based on earlier clauses, of factors which should be taken into account, in no particular order of priority, in determining suitable sensor 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) need to be assessed;
c) chemical and physical data of the potential gases/vapours present (for gas mixtures (for example, sour gas) the properties of the mixture as a whole should be considered);
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 or 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.

7.7 Installation of sensors

For the reliable operation of a fixed gas detection equipment each sensor should be placed in a suitable location according to its individual application, and as decided above.

However, inspection and maintenance, including recalibration with gas, need to 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 sensor can 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 toxic 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 damage the sensors.

Sensors shall be connected to their respective control unit, as specified by the manufacturer (observing maximum loop resistance, minimum wire size, isolation, etc.), and as applicable use a cable, wire and conduit system, or other system suitable and approved for the purpose, area classification, and suitable mechanical protection.

Installation of sensors should be carried out by a competent person.

7.8 Integrity and safety of fixed systems

7.8.1 General

If the gas detection equipment or channels of a system fail or are removed from service, so that areas of the plant cannot be monitored sufficiently, additional measures might 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 equipment, or a part of it, becomes inoperative during routine calibration and/or maintenance procedures.

Additional measures for safety 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 toxic gases or liquids;
f) switching-off of plants or parts of them;
g) duplication of the most essential sensors; and
h) establishing a thorough and timely maintenance procedure based on manufacturer’s instructions and any prior experience taking facility conditions into account.

7.8.2 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. Devices that operate 'fail safe' should be used wherever possible.

7.8.3 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 a fault signal.

   It is strongly recommended that for indication of power and/or equipment failure, signal outputs change state when the fault relay coil de-energizes.

7.8.4 Timing of installation during construction operations

Sensors should be installed as late as possible in any program 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, to avoid damage to the sensors 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. When an air-tight seal protection is used, it is imperative that all such protection be removed prior to commissioning and use.

7.9 Commissioning

7.9.1 Inspection

The complete gas detection equipment 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 local regulation. 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) of circuit(s);
f) perform a test to ensure the integrated system will indicate the full operating range of the detector(s) and initiate alarms or automatic shutdowns; and
g) perform a test to ensure the integrated system's latency is within specifications of the system.

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 sensing points. The instructions should include details on use, testing, calibration and operation, and should include all manufacturers' instructions.

7.9.2 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.

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 (for example, 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 4.2.2.3.

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

7.9.3 Adjustment of alarm set points

In the case of detection equipment only indicating up to the lower toxic 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 nuisance alarm signals.

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

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

Local regulations can exist which will determine the appropriate selection of alarm set points. End user policies or local regulations can also provide requirements for the alarm set points.

7.10 Operating instructions, plans and records

Each gas detection equipment or group of equipment is provided with an instruction manual. The manual should be available in a language the user can understand. IEC 62990-1 requires that it contains complete, clear, and accurate instructions for safe installation, use and maintenance of the equipment.

A system dossier should include the manuals for each piece of equipment as well as other relevant documentation regarding the system.

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 toxic gas detection equipment 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 detection equipment will require periodic recalibration using appropriate calibration gases. Where sensors are used that have definite service lives and/or susceptibility to poisoning (for example, catalytic, electrochemical, semi-conductor) regular recalibration, or at least response checking, will be required. The required frequency might 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 response checks to be found. If different intervals are defined, the shortest time period should be taken.

During periodic recalibration, the response time to the calibration gas should be recorded. Increases in response times can be an indication degradation of detector sensitivity.

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 equipment should be carried out and the test and alarm functions should be checked. Special attention should be taken to look for contamination (for example, 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; and
- safe operation of the system.

The results of all inspections should be recorded in the dossier.

8 Operation of toxic gas detection equipment

8.1 Alarm setting

Alarms and the measures to be taken when an alarm is activated should be specifically defined by a competent person for each scenario as a result of a hazard assessment. For many substances, the conditions for alarm activation (for example, set point, time weighted average values and their reference periods) are defined by guidance documents for the particular application.

Gas detection equipment usually has at least two independent, instantaneous alarms that are usually operated as a pre-alarm (low-level) and a main alarm (high-level). These alarms are activated when the measured value exceeds the respective set point. The pre-alarm allows for taking early intervention options before the gas concentration reaches the main alarm set point. One example is the activation of a ventilation system, which limits an increase in concentration by diluting with air. Activation of the main alarm requires further action, for example, evacuation. The main alarm is usually latching and the pre-alarm non-latching.

NOTE A latching alarm is an alarm that, once activated, requires deliberate action for deactivation.

Portable equipment usually has, in addition to instantaneous alarms, time weighted average (STEL and TWA) alarms. These alarms are activated when the calculated time weighted average value exceeds the respective set point. Typically, instantaneous alarms are used to warn against acute exposure to a dangerous concentration of toxic gas (safety), whereas STEL and TWA alarms can be used to warn against longer term health effects.

The alarm set points of the equipment should be set specifically for the application. The set point should be low enough that associated protective measures can be effective. Conversely, they should be set high enough that false alarms are avoided as far as possible. Frequent false alarms can lead to alarms being ignored. It is recommended that the lowest alarm set point should not be set below two times the lower limit of measurement for equipment conforming to Type HM equipment or below 10 % of the measuring range for equipment conforming to Type SM equipment.

When determining the alarm set points, all delays, for example, due to gas transport, time of response of the equipment, the protective measures taking effect, should be taken into account. Lower settings of the alarm set points lead to earlier alarm activation.

8.2 Operation of portable equipment

8.2.1 General

Effective operation of toxic gas detection equipment depends not only on its performance but also on the user having a sufficient knowledge of its correct usage and limitations. The performance of the equipment is affected by its condition (for example, cleanliness, dryness, and appropriate maintenance).

The user responsible for the equipment should read the instruction manual thoroughly and follow the instructions on functional check, calibration and other maintenance. All equipment requires inspection and functional checks, as well as maintenance, including calibration, adjustment and response time testing to be carried out at regular intervals by a competent person. Calibration and adjustment could require special equipment and reliable methods for generating known concentrations of gases. If the user is unable to carry out any of these activities the manufacturer or other competent persons or organisations will be able to advise on appropriate action.

Personnel required to use equipment should be properly instructed in their use and the actions to be performed in the case of alarm. Portable equipment including personal monitors should be located such that the ambient atmosphere has free access to the sensor inlet. Personal monitors should be worn close to the breathing zone.

Equipment should be handled with care in order to perform reliably. Dropping the equipment and subjecting it to unnecessary vibrations or extremes of temperature or humidity should be avoided. If the equipment is dropped, it will be necessary to carry out inspection and functional checks (see 8.2.13) before the equipment is used further.

High concentrations of gases above the indication range of the equipment can affect its reliable operation for a short or long time. If such exposure occurs, remove the equipment and operate it in a clean air environment until the measured value has stabilised. Calibration and adjustment should then be carried out. The sensor performance can still be affected afterwards, for example, longer time of response. Any additional information in the instruction manual should be followed.

Users should ensure that the equipment is suitable for use in the expected environmental conditions (see 6.5). The equipment should be protected from precipitation and dust.

Where sampling pumps and lines are used, it is good practice to use water traps to avoid the intake of water.

At low temperatures, for example, below 0 °C, batteries have a smaller capacity which reduces the operating time of the equipment. The operating time remaining after low battery indication can also be shortened.

8.2.2 Electrical protection in explosive atmospheres

Portable equipment should have a type of electrical protection which complies with the relevant explosion protection standards for the area of use (see IEC 60079-0).

8.2.3 Safety of personnel

When about to work in an area, it might be necessary to check on the potential for explosive, toxic or oxygen depleted atmosphere and to discuss hazards with the plant Safety Officer, Industrial Hygienist, or equivalent, particularly if confined spaces are involved.

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

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

8.2.4 Spot tests and sampling

The equipment will only detect gas in the location where the sensor or the sampling point is positioned. A toxic gas atmosphere can build up a distance from the detection point. A sufficient number of spot tests should be conducted initially around the intended area of work to minimize exposure.

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 (for example, 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 7.5).

Similarly, if light gases or vapours (for example, 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.

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

8.2.5 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 can 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 gas detection equipment or its accessories have been contaminated by liquid it shall be regarded as unusable until the contamination has been completely removed and the proper performance of the equipment has been verified, prior to returning it to service.

8.2.6 Avoidance of condensation

When taking 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 can cause contamination and/or incorrect readings.

Saturated steam can physically block the filters of certain types of gas sensor, making them inoperative, and care should be exercised accordingly.

8.2.7 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 sulphide, ammonia and chlorine, can cause inhibition of some toxic 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 toxic 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, electrochemical or semiconductor equipment shall be checked at frequent intervals.

8.2.8 Changes of temperature

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

8.2.9 Accidental damage

If portable 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.

8.2.10 “Read and run” concept

The read and run method should only be used when more robust techniques are not available such as use of a sample line for measurement from a distance. 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. The safety margins are increased if small changes in readings are observed, rather than only relying on alarms that are always set at a higher level.

Accuracy is not important as long as the equipment will respond to a response 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 might not be fully familiar with 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) Ongoing to the area where the tests are required, if there is any indicated change from the clean air reading, this is a ‘positive reading’.

d) When there is a positive reading in the area being monitored then GET OUT, which is "Read and run" in addition to warning all other personnel in the area to evacuate.

8.2.11 Transportation

Care should be taken when transporting equipment to and from the workplace. It is good practice to protect the equipment from:

a) large temperature changes;
b) large humidity changes;
c) unnecessary vibrations and mechanical shock;
d) direct sunlight;
e) low pressure, for example, less than 80 kPa, and rapid changes of pressure; and
f) precipitation and dust.

8.2.12 Storage

It is important that the equipment is stored in appropriate conditions. Factors to consider include:

- cleanliness of the storage environment;
- temperature and humidity of the storage environment; and
- absence of substances that could impair the performance of the sensor, such as solvents or known sensor poisons.

It should be considered that parts of the equipment can deteriorate with age, in particular sensors and batteries.

During storage, the equipment should be tested on a regular basis and batteries charged as appropriate. Some types of batteries, for example, nickel hydride, can discharge fully in a short time. Rechargeable batteries should be charged in accordance with the recommendations in the instruction manual.

After prolonged storage, a functional check and calibration should be undertaken.

8.2.13 Inspection and functional checks

Inspection and functional checks are intended to verify that the equipment is in a working state. It is strongly recommended that these checks are performed before each day of use.

For certain applications, for example, emergency response, there might not be sufficient time to conduct inspection and functional checks before use. In this case, an alternative plan for inspection and functional checks should be implemented which provides an equivalent level of safety.

The routine inspection and functional checks should include:

a) a check that the equipment is within its calibration period;
b) a visual inspection of the carrying case, equipment housing and sensor inlet for damage and contamination;
c) a visual inspection that all accessories are in good condition and free from contamination;

   EXAMPLE Typical accessories are cables, sample lines and sampling probes.

d) a check for aspirated equipment that there are no leaks in the sampling system;
e) a check to ensure that the batteries have sufficient charge;

f) a check of the zero reading in clean air. A significant non-zero reading can indicate a drift in sensor response or a malfunction of the electronics;

g) a simple function test of the equipment' response to gas. This can be undertaken by using a field calibration kit with the target gas or a surrogate gas subject to the manufacturer's recommendation; and

h) a check of the display and audible and/or visual alarms, if fitted. This test can be undertaken in conjunction with g).

The results of the routine inspection and functional checks should be recorded and any remedial action should be completed and verified prior to use.

8.3 Operation of transportable and fixed equipment

8.3.1 General

The subclauses of 8.2 should be taken into consideration for transportable or fixed equipment. Effective operation of transportable and fixed toxic gas detection equipment depends not only on its performance but also on the user having a basic knowledge of its correct usage, appropriate location and gas properties. The performance of the equipment is affected by its condition, for example, cleanliness, dryness, and appropriate maintenance.

Fixed equipment is used for area monitoring to provide information on the concentration of toxic gases over a site. For exposure measurements or personal protection, additional measures can be required, for example, portable equipment. The following types of fixed systems are commonly used:

a) Systems consisting of gas detection transmitters that are connected to a central control unit. These systems are suitable for the majority of industrial site monitoring applications. The response time of the whole system is mainly determined by the response time of the transmitter.

b) Systems where the gas is transported from the sampling point to the measuring equipment by a sample line. The response time of the whole system is determined by the response time of the central measuring equipment, the sampling flow rate and the sample line length.

c) Systems such as 8.3.1 b) but with more than one sampling point. The gas from each sampling point is sampled sequentially by the central measuring equipment. These systems should only be used where comparatively static process conditions are found. The response time of the system should be adequate for its intended use. The response time of the system is dependent on the number of sampling points and the measuring time at each sampling point. The measuring time at each sampling point is determined by the response time of the central measuring equipment, the sampling flow rate and the sample line length. It should be recognized that high concentration peaks of short duration will not necessarily be detected because the concentration at a single sampling point is not continuously measured. It should be recognized that contamination of sample lines can cause problems when sampling is switched to another line especially when high concentration points are being measured together with lines that are not sampling high concentrations. Consideration should be given to flush times between samples and block and bleed methods when switching lines.

The response time of the gas detection equipment should be sufficiently short to provide an alarm or executive action before a hazardous concentration of toxic gas occurs.

For the reliable operation of a fixed gas detection equipment, each transmitter or sampling point should be placed in a suitable location according to its individual application. Many factors should be considered when specifying the monitoring site and determining the number of sensors required, including industry standards and/or regulatory authority requirements. It is important that the manufacturer's installation manual is read thoroughly and the instructions followed.

High concentrations of gases above the indication range of the equipment can affect its reliable operation for a short or long time. Exposure to poisons can also adversely affect their operation.

If such exposure occurs, the equipment should be allowed to recover until the measured value is close to zero. A calibration should then be carried out. Any additional information in the instruction manual should be followed.

8.3.2 Commissioning and regular inspection

8.3.2.1 General

It is recommended that an initial gas calibration (7.9.2) is carried out after installation. Subsequently, both inspection (7.9.1) and calibration (9.7) should be periodically performed to ensure correct operation.

8.3.2.2 Commissioning

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

For maintenance and record purposes, plans of the installation should be provided that show the locations of all parts of the system (control units, gas detection transmitters, sampling points, etc.) together with the routes and specifications of all cables. The records should be updated when any changes are made to the installation.

After installation on site, each sensor should be calibrated and adjusted by a competent person according to the instruction manual.

8.3.2.3 Regular inspection

The gas detection equipment should be regularly inspected by a competent person. The inspection should be in accordance with the instruction manual and the specific requirements of the application. The intervals can be specified by the manufacturer or by any local regulations.

The inspection should include the following:

a) a check that the equipment is within its calibration period;
b) visual inspection of gas detection transmitters for mechanical damage;
c) visual inspection of the gas inlets or sample lines (for example, for contamination by dust or dirt);
d) visual inspection of all accessories, for example, sampling probe, weather protection, to ensure that they are in good condition and free from contamination;
e) visual inspection of the control unit to ensure that the system is fully operational; for example, inspection of the fault signals and alarm status of all the gas detection transmitters; and
f) triggering of test functions for display and visual indicators during operation without triggering switching outputs.

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

– periodic cleaning of filters, optical components, etc.;
– assembly of required materials, for example, auxiliary gas for some equipment; and
– safe operation of the system.

The results of the routine inspection should be recorded and any remedial action should be initiated immediately.

8.4 Sample lines and sampling probes

Sample lines are usually permanently installed in fixed installations. Sampling probes associated with transportable and portable equipment are usually short (of the order of 1 m) and rigid, however, they can be telescopic and can be connected to the equipment by a flexible tube. In the following, the term sample line includes sampling probe.

Consideration should be given to water condensation that can block the sample line, or lower the concentration and hence the measured value due to the gas sample dissolving in the liquid. This effect can be minimized by heating the sample line.

The material of the sample lines should be selected to avoid sorption or reaction of the gas being detected.

Any leakage in or out of the sample line should be prevented.

Sample lines should be as short as possible since the response time is determined by the overall length. Moreover, concentration peaks will be broadened by long sample lines. In addition, care should be taken to avoid dilution of the sample by leakage of air into the sample line.

The flow rate through the sample line should be monitored. A flow failure indication should be given when the flow rate falls below the minimum value required to meet the time to alarm necessary for the application.

Hazards arising from venting exhaust gas from the sampling system should be avoided.

Filters can be used to protect the equipment from dust and interfering gases or poisoning substances. A particulate filter can be required at each sampling point so that the sample line is kept clean internally. Additional devices are required for this purpose where mists can be sampled.

8.5 Accessories

The use of any accessory, for example, collecting cones, windshields, splashguards, chemical selective filters is likely to have some effect on the measurements. Normally, the main effect is on the sensitivity, time of response and time of recovery. The user should only use accessories for which the effect on the equipment' characteristics is known. This information can be obtained either from the manufacturer or from validation.

Filters can be used to protect the equipment from dust and interfering gases or poisoning substances. Filters increase both the time of response and the time of recovery.

The lifetime of filters is dose (the product of gas concentration and time) dependent for both dust and interfering gases. They should be checked and replaced regularly. For details, refer to the instruction manual.

Condensation, which can be liquid or frozen, can completely block the filter.

Accessories located near the sensor inlet, such as collecting cones and splashguards, should be cleaned regularly in order to avoid sorption resulting in false measurements.

9 Maintenance and calibration

9.1 General

Sensors have limited lifetimes and their sensitivity can change over time. Furthermore, some gases, corrosion, vibration and shock during transport can cause certain types of sensors to deteriorate. Dust and dirt can also impair gas transport to the sensor. This is a major reason for requiring frequent inspection and functional checks (see 8.2.13), maintenance and calibration of gas detection equipment.

Inspection and functional checks on portable equipment and regular inspection of transportable and fixed equipment can be carried out by the user.

Maintenance and calibration of all types of equipment should only be undertaken by trained personnel. If the user does not have a maintenance and calibration facility or trained personnel to carry out the work, then it should be performed by the manufacturer or another qualified organization.

9.2 Sensor

9.2.1 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. Periodic response time testing can be used to identify degradation in sensor performance. It is further recommended that sensors be evaluated after exposure to high concentrations of toxic gas, or exposure to inhibitors is suspected or after severe impact or mechanical vibration has occurred.

9.2.2 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.

9.3 Flow systems of aspirated equipment

9.3.1 General

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.

9.3.2 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.

9.3.3 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.

9.3.4 Flow connections

All flow connections should be tightened in accordance with the manufacturer's instructions.

9.3.5 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.

9.3.6 Automatic sample-draw systems

Automatic sample-draw systems should be adjusted to correct flow rate values using recommended test equipment.

9.3.7 Loss-of-flow signals

The loss-of-flow signals should be checked for proper operation.

9.4 Readout devices

9.4.1 General

Inspect all visual and electric outputs, and do not return the equipment to service if any of the outputs are found to be damaged. 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 up-scale and down-scale stops, etc.;
c) inspect digital meters for defects – for example missing segments, faded segments, etc.; and
d) conduct other electrical and mechanical meter tests which the equipment manufacturer deems necessary to assure proper performance.

9.4.2 Other readouts

Other readouts (for example, solid state) and outputs (for example, alarm outputs) that are incorporated should be tested (electrically) at specified test points according to the manufacturer's instructions.

9.5 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.

If alarm levels are not available for the application or cannot be determined initially for setup, then the lowest practical level indicated in the local regulations should be used until determination of appropriate alarm levels can be made.

9.6 Maintenance

The manufacturer’s instructions should be followed regarding the replacement of consumable parts and fitting of spare parts. Both types of parts should meet the specifications and tolerances of the original in order to maintain the specified performance of the gas detection equipment, and therefore its conformity to IEC 62990-1, and to maintain its electrical safety in explosive atmospheres, if applicable.

Consumables (for example, filters) should be checked and replaced regularly.

Spare parts (for example, electrochemical sensors) and consumables (for example, filters) can require specific storage conditions. Such spare parts and consumables can deteriorate in storage owing to unsuitable conditions or ageing.

The guidance on storage conditions and lifetime in the instruction manual should be followed. Spare parts and consumables should be used before any expiry date on the packaging.

If any portion of the gas detection equipment is found to be inoperative, refer to the instruction manual or contact the manufacturer for guidance on proper servicing of the equipment.

9.7 Calibration

9.7.1 Procedure

Calibration should be carried out in accordance with the instruction manual. The target gas should preferably be used for calibration. However, if recommended by the manufacturer, this calibration may be performed with a surrogate gas to which the equipment responds in a defined way. The use of surrogate gas introduces additional tolerances due to variability in the sensor manufacturing process. Relative sensitivities between surrogate gas and target gas can change over time. Information from the manufacturer concerning additional tolerances and any time limits on use of surrogate gas for calibration should be followed.

The calibration of gas detection equipment involves:

a) Preparation of calibration gas mixture(s)

   The preparation of gas mixtures in the concentration range of interest is often difficult. The easiest and most common method is to use a gas cylinder with a certified gas concentration. The expiry date of the gas mixture should be complied with. Note that different gas mixtures have different lifetimes. For gases that can adsorb on the cylinder walls, it is important to consider the minimum usable pressure or usage of special types of cylinders, which is typically user-defined. If a test gas mixture is not available in a gas cylinder, then the recommendation of the gas detection equipment manufacturer should be followed. Alternative methods of generating calibration gas mixtures include gas generators and permeation tubes.

b) Exposing the equipment to the calibration gas mixture(s)

   The manufacturer will generally provide a suitable calibration mask as an accessory for diffusion type equipment. An alternative for some gases is the use of an exposure chamber. For aspirated equipment, the gas should be applied at the gas inlet of the sample line (if any). For certain gases, however, due to difficulty of handling, calibration by the user is not advised by the manufacturer.

c) Adjusting the equipment zero and span

   Gas detection equipment should be installed and operated in such a way that unauthorized persons have no access to the controls. Software-based equipment usually have password-protected access. For the reliable operation of gas detection equipment, passwords or special access tools should only be accessible to authorized persons.

   The equipment is usually calibrated in two stages. Firstly, the sensor is exposed to zero gas and the zero adjusted to give the zero scale indication. Secondly, the sensor is exposed to the gas concentration for which the most accurate measurement is required or where the main alarm is set. The span is then adjusted to give the concentration reading.

   During the calibration procedure, the indication before any adjustment should be recorded and the values should be compared with those of previous calibrations. If this comparison leads to a result clearly different from the previous calibrations, appropriate remedial action should be taken, for example, shortening the calibration period or replacement of the sensor. In this case, all measurements since the last calibration should be questioned.

9.7.2 Calibration period

The calibration and, if necessary, adjustment procedures demonstrate that the gas detection equipment is able to measure the target gas with sufficient accuracy. However, between the calibrations, the performance of the equipment is unknown and the deviations are likely to increase with time. The calibration period should therefore be chosen appropriately.

When choosing the calibration period, factors such as sensor characteristics, type of equipment, static and dynamic conditions of temperature and humidity, dust, poisoning, corrosive atmospheres and experience of the user in similar situations, should be considered. Appropriate calibration periods can range from days to months.

It is good practice to determine the calibration period as follows:

a) if there is sufficient reliability and stability data available for the equipment and sensors used in a specific application, the calibration period can be derived from this data for applications with similar operating conditions;

b) if sufficient data is not available, two calibrations should be conducted at short intervals following commissioning. If it is not necessary to adjust the equipment at these calibrations, the interval can be increased. This procedure should be repeated until the calibration period specified in the instruction manual is reached; and

   EXAMPLE An appropriate short interval could be four weeks.

c) if adjustment is necessary at two successive calibrations, the calibration period should be shortened until no such adjustment is necessary. If, however, the final calibration period is unreasonably short, a more suitable sensor, equipment or measuring principle should be considered.

An adjustment is necessary if the deviation of the measured value is outside the limits required by the application or if the minimum requirements for stability of the equipment as defined in IEC 62990-1 are not met. Type HM equipment requires that the deviation within one calibration period should not exceed the lower limit of measurement in clean air and 20 % of the measured value in test gas. Type SM equipment requires that the deviation within one calibration period should not exceed 10 % of the measuring range in clean air and 20 % of the measured value in test gas.

9.8 Operation test

The operation test should demonstrate that the equipment is able to perform its intended function. The operation test should include:

a) calibration (see 9.7);
b) test of the whole safety function, from the gas inlet or measuring point to the executive action (for example, initiating mechanical ventilation, audible and visual alarms);
c) comparison of the response time or time to alarm of the equipment (including sample line if fitted) with the specification;
d) verification of parameter settings;
e) a check of the signalling and recording devices;
f) a check that rechargeable batteries have sufficient charge; and
g) a check of the condition of accessories and consumables (for example, hoses, filters) which should be replaced if necessary.

The operation test should be performed at the time of commissioning and repeated at regular intervals, for example, 1 year.

9.9 Records

It is good practice to record the use, maintenance and calibration of each equipment. This comprises:

a) location for fixed equipment and of any changes;
b) maintenance history;
c) calibration record;
d) record of regular inspections and functional checks;
e) record of operation tests; and
f) record of the use of the equipment, for example, the date used, the measurement task, the name of the operator, etc.

Records should be retained in a secure location for future reference.

10 Training

10.1 General

For most equipment, training is required for both the operator and those responsible for its maintenance and calibration. A distinction is made between training for operators and training for those responsible for maintenance and calibration because, generally, those operating the equipment will not be responsible for its maintenance and calibration.

Training should be performed by persons competent to train and knowledgeable about the equipment and its use.

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

Periodic refresher training courses should be given.

Records should be kept of the training of personnel involved in the operation, maintenance and calibration of the equipment.

10.2 Operator training

Operator training should be designed to ensure the full understanding of the operation of the equipment including:

a) checks before use;
b) battery and functional checks;
c) the operation of a fixed gas detection equipment and the interactions between the individual components (for example, control unit, transmitters, sampling system)
d) operation of the visual and audible warning systems; and
e) whom to contact if the gas detection equipment is believed to be malfunctioning.

It is particularly important that operators should have instructions to be followed in the event of a gas detection equipment alarm, fault or other special state.