UL 920002

STANDARD FOR SAFETY

Installation, Operation, and Maintenance of Toxic Gas-Detection Instruments

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UL Standard for Safety for Installation, Operation, and Maintenance of Toxic Gas-Detection Instruments, UL 920002

First Edition, Dated September 30, 2013

Summary of Topics

This revision of ANSI/UL 920002 dated September 24, 2021 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

Adoption of ANSI/ISA-92.00.02-2013, Standard for Installation, Operation, and Maintenance of Toxic Gas-Detection Instruments as ANSI/UL 920002. As noted in the Commitment of Amendments statement located on the back side of the title page, UL and ISA are committed to updating this co-designated standard jointly after processing according to the standards development procedures by UL.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

These requirements are substantially in accordance with Proposal(s) on this subject dated June 25, 2021.

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ISA – The International Society of Automation
ANSI/ISA-92.00.02-2013 (R2021)
First Edition

Underwriters Laboratories Inc.
ANSI/UL 920002
First Edition

Installation, Operation, and Maintenance of Toxic Gas-Detection Instruments

September 30, 2013

(Title Page Reprinted: September 24, 2021)

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Approved American National Standard

ANSI/UL 920002-2013 (R2021)

Commitment for Amendments

This standard is issued jointly by ISA and Underwriters Laboratories Incorporated (UL). Comments or proposals for revisions on any part of the standard may be submitted to UL at any time.

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CONTENTS

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General Notes

This is the common ISA and UL, Standard for the Installation, Operation, and Maintenance of Toxic Gas-Detection Instruments. It is the first edition of ANSI/ISA-92.00.02 and the first edition of ANSI/UL 920002. The document is a modification of the ISA document to create the equivalent UL version and maintain the ANSI approval of this standard.

ANSI/ISA-92.00.02 and ANSI/UL 920002 contain identical requirements, and identical publication dates.

This common standard was prepared by the (ISA) - The International Society of Automation on September 30, 2013 but is now being maintained by Underwriters Laboratories Inc. (UL).

Note: Although the intended primary application of this standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.

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Preface (ISA)

This preface, as well as all footnotes and annexes, is included for information purposes and is not part of ANSI/ISA-92.00.02-2013 (R2021).

This document has been prepared as part of the service of ISA toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static but should be subject to periodic review.

The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrumentation standards. The Department is further aware of the benefits to USA users of ISA standards of incorporating suitable references to the SI (and the metric system) in their business and professional dealings with other countries. Toward this end, this Department will endeavour to introduce SI-acceptable metric units in all new and revised standards, recommended practices, and technical reports to the greatest extent possible. *Standard for Use of the International System of Units (SI): The Modern Metric System*, published by the American Society for Testing & Materials as IEEE/ASTM SI 10-97, and future revisions, will be the reference guide for definitions, symbols, abbreviations, and conversion factors.

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INTRODUCTION

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

Equipment may be used to monitor a gas atmosphere below the applicable level, (PEL, REL, TWA, STEL or IDLH), limit in circumstances where accumulation of toxic gas may result in a concentration of the gas/air mixture to potential risks to life and health. Performance requirements for gas detecting equipment for such purposes are set out in ANSI/ISA-92.00.01 and ISA-92.00.04. However performance capability alone cannot ensure that the use of such equipment will properly safeguard life or property where toxic gases may be present. The level of safety obtained depends heavily upon correct selection, installation, calibration and periodic maintenance of the equipment, combined with knowledge of the limitations of the detection technique required. This cannot be achieved without responsible informed management.

Portable equipment covered by the ANSI/ISA-92.00.01 and ISA-92.00.04 commonly have additional detectors for combustible gases and also for oxygen deficiency. Users are cautioned that even mild oxygen deficiency may be due to toxic concentrations of some other gas or vapor, which may not be detectable or adequately detected by the equipment in use. This concept must not be relied upon for detection of a non-monitored toxic gas because 0.1% oxygen reduction can mean 1,000 ppm or greater of the unknown toxic gas, which usually exceeds most toxic gas safety limits. All toxic gases suspected should be monitored by the proper equipment.

Minimum requirements for the instruction manual of any particular toxic gas detection equipment are specified in ANSI/ISA-92.00.01 and ISA-92.00.04. These standards provide some necessary background knowledge on the points mentioned above.

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

The following table gives a broad suggestion as to the most relevant clauses to the typical tasks to be performed.

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Table 1
Functional applicability

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

"+++" Essential

"++" Advisable

"+" Useful

"–" Not applicable

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

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

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1 Scope

This standard gives guidance on, and recommended practice for, the selection, installation, use and maintenance of electrically operated equipment intended for use in industrial and commercial safety applications for the detection and measurement of toxic gases complying with the requirements of ANSI/ISA-92.00.01 and ISA-92.00.04.

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

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

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

Similarly it is applicable to the safe use of portable or transportable equipment, irrespective of the age or complexity of such equipment. Since much modern equipment of this type also includes other types of gas detection, some additional guidance is given for these topics.

NOTE Equipment intended for use in hazardous (classified) areas should be Listed or Labeled for use within the intended area. For fixed equipment, installation should be in accordance with the National Electrical Code, ANSI/NFPA 70.

For the purposes of this standard, except where specifically stated otherwise, toxic gases shall include toxic vapors. For the purposes of this standard, equipment includes

a) fixed equipment;

b) transportable equipment, and

c) portable equipment.

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

a) equipment of laboratory or scientific type intended only for analysis or measurement purposes;

b) equipment intended for underground mining applications (group I equipment);

c) equipment intended only for process control applications;

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

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

2 References

The following referenced documents are indispensable for the application 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.

ANSI/ISA-12.13.01, Performance Requirements for Combustible Gas Detectors

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ANSI/ISA-60079-29-2 (12.13.02), Explosive Atmospheres – Part 29-2: Gas detectors – Selection, installation, use and maintenance of detectors for flammable gases and oxygen

ANSI/ISA-12.13.04, Performance Requirements for Open Path Combustible Gas Detectors

ANSI/ISA-92.00.01, Performance Requirements for Toxic Gas Detectors

ANSI/ISA-92.04.01, Performance Requirements for Instruments Used to Detect Oxygen-Deficient/Oxygen-Enriched Atmospheres

National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards, Title 29, Part 1910.1000, Occupational Safety and Health Standards

Threshold Limit Values for Chemical Substances in the Work Environment Adopted by the American Conference of Governmental Industrial Hygienists (ACGIH)

Documentation for Immediately Dangerous to Life or Health Concentrations (IDLHs) (NIOSH Taft Laboratories)

OSHA 29 CFR1910, 1000 OSHA Regulation on Air Contamination

API RP55 Conducting Oil and Gas Producing and Gas Processing Plant Operations Involving Hydrogen Sulfide

MSDS sheets for all gases/vapors present and/or suspected in the site being monitored.

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in the standards referenced in Clause 2, as well as the following apply. Also, since this is intended as a stand-alone standard, certain definitions within ANSI/ISA-92.00.01 are repeated below for the convenience of the reader.

3.1
alarm:
an audible, visual, or physical signal that alerts the instrument user of a dangerous gas concentration or instrument problem

3.1.1
false alarm:
any alarm that is triggered by a condition other than the one(s) that the alarm function is set for (ex: high gas alarm caused by RF interference or gas alarm caused by temperature changes)

3.2
alarm-only equipment:
equipment having an alarm, but not having a meter or other indicating device.

3.3
alarm setpoint:
the selected gas concentration level(s) at which an alarm is activated.

3.4
ambient air:
air to which the sensing element is normally exposed.

3.5
bump test:
application of test gas or other means of obtaining a response from the sensor to check its function. This may include the generation of an alarm. This check is performed without adjustments of sensitivity.

NOTE – This is also known as a “response check” or “functional check”.

3.6
calibration:
the procedure to adjust the equipment for proper response (e.g., zero level, span, alarm, and range).

3.7
calibration gas:
the known concentration(s) of gas used to set the equipment span or alarm level(s).

3.8
clean air:
air that is free of any substance that will adversely affect the operation of or cause a response from the equipment.

3.9
consumables:
materials or components that are depleted or require periodic replacement through normal use of the equipment.

3.10
control unit:
that portion of a gas detection equipment that is not directly responsive to the gas, but which responds to the electrical signal obtained from one or more detector heads. This unit is intended to provide meter indication, alarm functions, output contacts and/or alarm signal outputs when utilized with a detector head.

3.11
detector head:
the gas responsive portion of a gas detection equipment located in the area where sensing the presence of gas is desired. It may be integral with or removed from its control unit.

NOTE – The detector head may incorporate, in the same housing, circuitry such as signal processing or amplifying components or circuits in addition to the gas sensing element (sensor).

3.12
diffusion:
a process by which the atmosphere being monitored is transported by natural random molecular movement to and from the gas-sensing element.

3.13
field check with gas (response check):
application of test gas to the sensor to check the response signal or the generation of an alarm, without adjustments of zero, sensitivity, or alarm level.

3.14
full-scale:
the maximum claimed operational level of the gas-detection equipment.

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3.15

gas-detection equipment:

an assembly of electrical and mechanical components (either a single integrated unit or a system comprised of two or more physically separate but interconnected component parts) which senses the presence of a gas and responds by providing an alarm, indication, or other output functions.

3.16

gas-sensing element:

the particular subassembly or element in the gas-detection equipment that, in the presence of a gas, produces a change in its electrical, chemical, or physical characteristics.

3.17

indication:

a discrete communication of a measured value or alarm condition.

3.18

IDLH (Immediately Dangerous to Life and Health):

the maximum concentration from which, in the event of respirator failure, one could escape within 30 minutes without a respirator and without experiencing any escape-impairing (e.g., severe eye irritation) or irreversible health effects.

3.19

mobile equipment:

a continuous-monitoring equipment mounted on a vehicle, such as, but not limited to, a mining machine or industrial truck.

3.20

nominal voltage:

the voltage given by manufacturers as the recommended operating voltage of their gas detection equipment. If a range (versus a specific voltage) is given, the nominal voltage shall be considered as the midpoint of the range, unless otherwise specified.

3.21

PEL (Permissible Exposure Limit):

time-weighted average (TWA) concentration that must not be exceeded during any 8-hour work shift of a 40-hour work week, as defined by the Occupational Safety and Health Administration (OSHA).

3.22

portable equipment:

spot-reading or continuous duty equipment that has been designed to be readily carried from place to place and to be used while it is being carried. A portable equipment is battery powered and includes, but is not limited to

a) a hand-held equipment, typically less than 1 kg, suitable for single-handed operation;

b) personal monitors, similar in size and mass to the hand-held equipment, that are continuously operating (but not necessarily continuously sensing) while they are attached to the user; and

c) larger equipment that can be operated by the user while it is suspended by hand, by a shoulder strap or by a carrying harness; it may or may not have a hand directed probe.

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3.23
REL (Recommended Exposure Limit):
exposure levels that are safe for various periods of employment, including but not limited to the exposure levels at which no employee will suffer impaired health or functional capacities or diminished life expectancy as a result of that work experience.

3.24
range:
the values of concentrations of toxic gas over which accuracy is ensured by calibration.

3.25
spot-reading equipment:
equipment intended to be used for short periods of time as required (typically 5 min or less).

3.26
sample-draw:
a method to cause deliberate flow of the atmosphere being monitored to a gas-sensing element.

3.27
signal-processing detector head:
an equipment intended to be incorporated with separate signal processing, data acquisition, central monitoring, or other similar systems in which the equipment provides a conditioned electronic signal or output indication to systems of the aforementioned type that typically process information from various locations and sources including, but not limited to, gas-detection equipment.

3.28
span:
the algebraic difference between the upper and lower values of a range.

3.29
stabilization:
state when three successive readings of an equipment, taken at intervals equal to the maximum t(90) value defined in Annex A (Item 5), indicates no changes greater than the accuracy value defined in Annex A (Item 2).

3.30
stationary equipment:
a gas-detection equipment intended for permanent installation in a fixed location.

3.31
(TLV-)STEL, (Threshold Limit Value-) Short-Term Exposure Limit:
a 15-minute Time-Weighted Average (TWA) exposure that should not be exceeded at any time during a workday, even if the 8-hour TWA is within the Threshold Limit Value – Time-Weighted Average (TLV-TWA).

3.32
test gas:
toxic gas diluted with clean air or inert gas to a known concentration within the test-gas tolerance stated in Annex A, Item 1.

3.33
transportable equipment:
equipment not intended to be portable, but which can be moved readily from one place to another.

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3.34
(TLV-)TWA, (Threshold Limit Value-) Time-Weighted Average:
the time-weighted average concentration for a normal 8-hour work day in a 40-hour work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

3.35
toxic gas:
toxic gases, for the purpose of this standard, are gases that may cause significant health effects at low concentrations. Health effects may include severe skin or eye irritation, pulmonary edema, neurotoxicity, or other potentially fatal conditions.

3.36
trouble signal:
information that alerts an equipment user to abnormal conditions.

3.37
stand-alone gas detection equipment:
a detector which provides a conditioned electronic signal or output indication to a system. The stand-alone detector head is intended to be interfaced to unspecified separate control unit, signal processing data acquisition, central monitoring, or other similar systems in which the equipment provides a conditioned electronic signal or output indication to systems.

3.38
stand-alone control unit:
fixed gas detection control units intended to provide meter indication, alarm functions, output contacts and/or alarm signal outputs when utilized with stand-alone detector head.

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4 Basic information on the properties, behaviour, and detection of gases and vapors

For this clause, a distinction is drawn between gases, which remain gaseous at typical ambient pressures and temperatures, and vapors where liquid can also exist at any relevant pressure or temperature.

4.1 Detecting gases and vapors – General

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

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

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

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

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

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

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

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

4.1.1 Safety when monitoring for toxic gases where personnel could be present

Personnel should frequently observe the reading on any gas detection equipment when entering a potentially hazardous area. The area may already be dangerous and the personnel may need expedient warning of this danger. It is recommended that if methods of pre-testing an area to be entered prior to entry are available that these methods be used.

The equipment will only give a reading for the location where the reading is being taken, or the location of the end of the sampling line if a sampling line is being used. A toxic atmosphere may be building up a few meters from the sampling point. Therefore, many gas tests must be done all around the intended area of work to ensure that no pockets of hazardous gas or vapor are present in the work area. Checking all corners of the location and all entry/exit passages where gas may enter, even if continuous portable/transportable gas monitoring equipment is being utilized.

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

The readings are only valid for the time they are taken. Circumstances change. Frequent readings are recommended, particularly if vapors (see 4.3.2) could be involved and the temperature is rising.

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

If the equipment being utilized detects combustible gases in addition to toxic gases and there is a chance of sensor “poisons” (such as silicones, leaded petrol, acids, etc.) being present then the sensitivity of equipment using catalytic combustion or semiconductor sensors should be checked at frequent intervals.

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

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

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

Therefore, when about to work in a hazardous area, it is advisable to specifically check on the potential toxicity of the atmosphere with the plant safety officer, industrial hygienist, or equivalent.

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

4.2 Some common properties of gases and vapors

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

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

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

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

Air has an equivalent molecular mass of approximately 29, corresponding to a relative density of 1. For instance, gases with lower molecular masses than 29 will have a relative density less than 1 and will be lighter than air and as a result, rise to the upper portion of the space being entered.

Mixtures of fresh air with pure or mixed gases that are lighter than air, will still be lighter than air, but less so. They will tend to rise until they become so diluted with fresh air that the effect may become negligible.

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

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

Because of temperature differences at release and normal turbulence, gases and mixtures with relative density between 0.8 and 1.2 generally can be considered as having a similar relative density to air, and therefore are capable of propagating in all directions.

All vapors except water vapor are toxic to varying degrees. All flammable vapors are toxic at levels well below 25% LFL and most are toxic below 1% of LFL. All gases (except air or oxygen) are asphyxiants (i.e.

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their effect on personnel is due to dilution of the oxygen content of the air and may also vary from mild to extreme toxicity.

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

4.3 The differences between detecting gases and vapors

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

4.3.1 Detection 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. Basically, simple training may be adequate.

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

4.3.1.1 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 more than one toxic gas (or vapor) may need to be detected, it is normally necessary to use separate calibration gas for each toxic gas intended to be detected. For further details see 4.3.2.1.

4.3.1.2 Propagation and sampling considerations

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

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

4.3.1.3 Water vapor

Although this subclause relates only to detecting gases, it is not normally possible to ignore water vapor. This can produce problems in cold equipment that have been suddenly exposed to a hotter and humid atmosphere. Examples of this situation are in leaving a cold store and entering a normal atmosphere, or in leaving an air-conditioned situation and entering into a humid tropical or sub-tropical atmosphere. Water can condense in or on a sensor, causing a temporary loss of sensitivity or some other problem, until the equipment warms up and the water re-evaporates. This is particularly the case with electrochemical sensors: A very rapid drop in an oxygen reading can occur from a normal 20.8 % or 20.9 % reading to 16 % or lower, due only to a coating of water condensing onto the cold sensor membrane. The sensitivity may then only recover slowly over some minutes as the sensor warms up to ambient, and the film evaporates. This is why most gas detector manufacturer’s manuals indicate that performance of the equipment is based on non-condensing atmospheres.

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

4.3.2 Detection of vapors

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

Where a liquid is present, the rate of evaporation will increase with temperature. Similarly the maximum volume fraction of the vapor that can be achieved in a closed system (saturated vapor) 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 vapor 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 vapor 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 vapor 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 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 vapor at or above the boiling point at that atmospheric pressure. Below the boiling point of the liquid, the maximum possible concentration of vapor in air or other gases must be less than 100 % volume fraction.

The actual amount of vapor 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 liquids have flashpoints, which are determined in a different way from LFL, but are essentially the temperatures at which their vapors can reach their LFL volume fractions in the air above their liquid surfaces, again provided that the vapor is not continuously removed by air currents. Toxic vapors can be present when the vapor is well below a flammable level.

All of these points impose limits on mixtures of vapors with gases. For any particular volume fraction of a vapor in a mixture with gas, a fall in temperature or increase in pressure will, at a certain stage, reach the saturation point, below which liquid will start to condense as a fog or liquid. When applied to water vapor this is known as the “dew point”. This term is frequently applied to other vapors. Below the dew point the composition of any vapor-gas mixture must therefore change.

4.3.2.1 Calibration considerations

Real restrictions on what calibration or test vapors 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.

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

4.3.2.2 Propagation and sampling considerations

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

All other vapors are more dense than air. Most are considerably more dense than air. At a point of release, unless heated, they will initially flow downwards or across level surfaces, and until they are well mixed with air they will stay close to the ground, possibly only a few centimeters 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 meters. This can also cause the most serious toxicity problems for personnel entering pits and tunnels.

When sampling for toxic vapors in relatively undisturbed atmospheres, some tests must be performed at very low levels, ideally within a centimeter of the floor or ground.

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

The vapor of a high flashpoint toxic liquid may not be detectable if the ambient temperature is well below the flashpoint. As an example, using the rule of thumb at the beginning of 4.3.2, if the ambient is 60 K below the flashpoint, it can be estimated that the vapor can only reach between 1 % and 8 % of LFL as a maximum, and then only slowly, close to the liquid, and if the vapor is not being blown away.

Conversely, if the temperature rises, and particularly in an enclosed area, the concentration can change dramatically. Again, using the rule of thumb, the vapor 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 vapor while the tank was cold could become very significant when it is heated up. When temperatures are rising, frequent vapor testing is necessary.

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

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Major problems also arise in vapor testing due to the possible condensation of the sample itself in the detector or its accessories: Gas detectors will only detect the gases or vapors 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 sampling line gets contaminated by condensed vapor 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.

4.3.2.3 Toxicity and other considerations

All vapors except water are toxic to some degree. All toxic vapors are toxic at concentrations well below LFL. Most vapors, including many commonly found in industry, are of toxic concern well below 20 % of

LFL. So they may be undetectable at concentrations where they are already a toxic problem if only using a toxic gas detector with a normal LFL range. Additional precautions are needed.

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

4.4 Oxygen deficiency

Oxygen deficiency detectors are frequently incorporated with combustible gas equipment, with or without toxic sensors as well. Such oxygen detectors are essential for work in confined spaces conforming with the requirements of ANSI/ISA-92.04.01.

Some varieties of oxygen sensors respond to changes in pressure, and so need checking in fresh air, and possibly adjusting, each time they are used and/or if there is a significant change of altitude.

The volume fraction of oxygen in dry air is about 20.9 % v/v. A typical oxygen deficiency alarm setting is between 19.0 % to 19.5 % v/v.

Taking as an example a setting of 19.0 % v/v, the alarm should operate on a 1.9 % v/v deficiency or, put another way, a deficiency of 9.1 % of the original concentration. In certain circumstances this may not be adequate for personnel protection.

Similarly, with a setting of 19.5 % v/v, the alarm should operate on a 1.4 % v/v deficiency or, put another way, a deficiency of 6.7 % of the original concentration. In certain circumstances this also may not be adequate for personnel protection on its own.

It is not commonly appreciated that if an operator is relying on equipment to detect a toxic gas or vapor and a deficiency of oxygen, it is also necessary to know what could be the cause of any oxygen deficiency found.

There are three basic physical and chemical mechanisms by which oxygen deficiency can occur, described in the next three subclauses with reference to the 19.5 % v/v alarm setting example above.

4.4.1 Chemical reaction of oxygen, with solid products

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

When the alarm operates at 19.5 % v/v, the atmosphere is equivalent, in physiological terms, to working at an altitude about 650 m higher than the current altitude. Normally this will not cause any health problem to personnel.

4.4.2 Chemical reaction of oxygen, with gaseous products

In the simplest case this could be the result of respiration, aerobic bacterial action (but not anaerobic action), or clean combustion. The 1.4 % reduction in oxygen content needed to set off the alarm would be accompanied by an increase in carbon dioxide level of about 0.8 %, which is fairly safe in the short term, and there would be no short-term or long-term effects on a ‘normal person’.

If, however, the oxygen deficiency was the possible result of ‘dirty’ combustion involving wood, paper, coal, oil, etc., then, even after the smoke had settled, an atmosphere with 19.5 % v/v oxygen remaining could be lethally toxic due to amounts, possibly in excess of 0.2 % v/v (2000 parts per million), of carbon monoxide produced together with the carbon dioxide.

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

4.4.3 Dilution of the air by displacement

Dilution of the air by displacement by some other gas or vapor is only recommended under very controlled conditions and is not otherwise recommended.

WARNING – Detection of an unknown gas or vapor by an indication of Oxygen Deficiency is only recommended as a pre-entry test of an area to be entered. The actual reason for the low Oxygen reading must be determined prior to entry. The information provided below in this section are only examples of possible reasons for low Oxygen readings and must not be used to preclude determination of the actual cause of the deficiency.

The 1.4 % v/v oxygen deficiency needed to cause the alarm would require an addition of 6.7 % v/v of the other gas or vapor. It is imperative to be aware that a reduction in concentration of oxygen within an atmosphere could indicate the presence of a combustible or toxic gas or vapor that may be displacing the oxygen in the area. In this case, it is recommended that methods of detection for combustible and/or toxic gases or vapors be used for determination of the reason for the low oxygen reading. A survey should be conducted well in advance of entry into areas of concern.

It should be known what gas or vapor might be available to cause oxygen depletion. There are several categories:

a) If the cause of the oxygen deficiency is dilution by one of the inert gases such as nitrogen, argon, helium or neon, (or water vapor) an addition of 7 % v/v of the inert gas to the atmosphere is perfectly safe. The situation is similar to that in 4.4.1.

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

c) If the gas causing the oxygen deficiency is acetylene, ethylene, cyclopropane, propane, LPG or butane, the atmosphere would possibly be survivable by persons working in the area for a few seconds at least. But it would be above the LFL. So if there was a toxic sensor as well, this would alarm first.

d) If the gas causing the oxygen deficiency is carbon dioxide, the atmosphere would be marginal. Persons could only stay conscious in such an atmosphere for a short while. A 7 % volume fraction of any other gas or vapor added to the atmosphere, causing that amount of oxygen deficiency, would render the atmosphere potentially and rapidly fatal.

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

This may lead to a very dangerous situation. Reliance on oxygen alarms to monitor the production of carbon dioxide has led to fatalities. These were due to confusion between the situation in 4.4.2, where oxygen is subtracted and the alarm operates with around 0.8 % v/v CO_2, and the production of CO_2 by anaerobic processes. The latter situation is covered in this subclause, where CO_2 has been added without subtraction of oxygen, for instance in beer or wine making or by anaerobic slime in manholes. In these cases, the same alarm will not operate until there is 7 % v/v CO_2.

WARNING – An additional danger in this case is that some oxygen sensors give a small upscale signal with high concentrations of CO_2.

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In the example above, this means that the O_2 reading will be higher than the actual concentration of O_2, and the 19.5 % v/v O_2 alarm would only be given at a significantly higher (and therefore more dangerous) concentration of CO_2 than 7 % v/v.

5 Measuring principles

The measuring principles are handled in full detail in Annex A. This clause provides practical information for aspects of operation, servicing and repair. For more detailed information please use Annex A instead of this clause.

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

5.1 General

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

For equipment for the detection of toxic gases, and related equipment, there are two independent categories of test:

– Performance test – To ensure that devices are suitable for the detection of those gases and ranges they are designed for.

NOTE 1 Assessment of the toxic gas detecting equipment against the performance requirements specified in ANSI/ISA-92.00.01 may provide a basis for judgment in appropriate circumstances.

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

NOTE 2 Conformance to explosion protection techniques in ANSI/ISA-60079 series standards is essential to the safe use of equipment. This applies to all parts of the equipment, including sensors for other gases. Testing, selection and marking should comply to the appropriate national regulations. This is mandatory for all applications.

WARNING Area classification and equipment certification standards assume oxygen concentrations that do not exceed 21%.

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5.2 Selection criteria

5.2.1 General criteria

5.2.1.1 Criteria of selection of appropriate gas detection equipment

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

a) the gas(es) which the equipment is required to detect, the range of concentrations of each gas which may be encountered, and therefore the range and accuracy required;

b) the presence of potentially interfering gases;

c) the intended application of the equipment, for example area monitoring, personnel safety, leak detection or other purposes;

d) whether the equipment is required to be fixed, transportable or portable; For details, advantages, and restrictions of the three types, see Clauses 8 and 9;

e) the type of sampling system; diffusion or aspirated. For details and restrictions of both types see 5.2.3.1 and 7.2.2.8;

f) the classification of the intended area(s) of use in accordance with national regulations;

g) the environmental conditions that will be met in the area(s) of use, and comparison of this with the specifications of the proposed equipment;

h) the materials of the sensors and housings and their compatibility with the anticipated operating environment (corrosives, wind, rain, hosing, etc.). Copper components should not be exposed where acetylene may be present because of the potential to form explosive acetylides;

i) any features of particular equipment that require caution to be taken in the use or interpretation of its output; j) time dependency and interaction with safety devices and alarms (see 10.7);

k) calibration requirements including zero checks;

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

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

– the equipment is used to detect gases for which it is not calibrated;

– the gas sample is not conditioned to remove water vapor or other interfering vapors or gases, some of which may result in a negative response;

– variations in ambient conditions (without compensation) influence the response of the specific sensor type;

– the equipment may be susceptible to external radio frequency interference which causes malfunctions such as apparent errors in calibration, zero drift and false alarm signals.

5.2.1.2 Delay times

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

a) potential release rate of toxic gas;

b) delay time of the sampling system;

c) response time of the sensor;

d) delay time of data transmission lines;

e) delay time of alarm devices and switching circuits;

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

g) time taken for any decisions and manual intervention;

h) degree of personnel training.

5.2.2 Gases to be detected by the equipment

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

Where a range of gases is likely to be present in an area to be monitored, it is recommended that a detector, or detectors be selected that have been calibrated to each of the individual gases. Toxic gas sensors are generally specific to only one gas for which it is calibrated. Gas sensors with broad range capability should be calibrated to the gas and range to which it is least sensitive. However, care should be taken to ensure that the sensors so calibrated will remain adequately sensitive to the other gases likely to be present. If this is not practicable, then an alternative approach is to select separate sensors, calibrated to the different gases likely to be present.

When a mixture of gases of known relative concentration is to be monitored, it is recommended that this mixture is used for calibration, if at all practicable. When the composition of a mixture is unknown, it is critical to analyze the atmosphere before proceeding with sensor selection or calibration.

Those parts of the gas detection equipment that are located in, or may be taken into, a hazardous area should be certified for the gases that may be encountered.

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

– ensure the minimum oxygen concentration for correct functioning of equipment for the detection and measurement of toxic gases and vapors;

– ensure the maximum oxygen concentration permitted is not exceeded;

– monitor any increase in oxygen concentration which may increase the upper explosion limit and may decrease the energy required for ignition;

– protect personnel.

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5.2.3 Intended application of the equipment

5.2.3.1 Fixed equipment and fixed systems

Fixed equipment and fixed systems should be used where permanent gas monitoring in selected areas of a plant or other installation is required. These areas may be static as in manufacturing plants or mobile as in transportable systems.

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

According to the specific application, the suitability of the whole system has to be assessed, including the selection and the approximate number and placement of sensors or sampling points (see 8.2), the alarm levels and the response time. It may be appropriate to obtain advice from equipment manufacturers or a suitably trained person.

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

There are three main types of fixed equipment that are commonly used.

a) Equipment having the sensor and control unit situated within the hazardous (classified) area. In this situation the sensor and control unit may be combined or supplied as separate items.

b) Equipment having one or more sensors separate from the control equipment. This type of equipment usually consists of individual sensors in the hazardous (classified) area, connected to the associated control equipment in a safe area.

NOTE 1 This is the most suitable type for the majority of industrial applications, particularly if a rapid response is required. This is because the control unit is generally monitored on a regular basis i.e. located in a control room.

c) Sampling equipment. This type of equipment usually consists of one or more sampling points in the hazardous (classified) area, connected to a sensor by means of aspirated sample lines made of suitable materials which are compatible with the sample (see 8.3.3). It may be more suitable than types a) or b) where comparatively static process conditions apply and where conditions (environmental or accessibility) at the same point are unfavorable to the sensor, for instance there can be a wider temperature tolerance. Another advantage is that it can permit the electrical parts of the system to be located out of the hazardous area, in which case, apart from using flame arrestors where sampling lines pass from a hazardous to a non- hazardous area, specific hazardous area compliance may not be required. Such flame arrestors can consist of sintered metals, capillary holes, or other fine gaps, for operation. These devices may increase the response time, may be affected by corrosion, and may be prone to blockage by dust or condensation. This means specific examination and maintenance is required. Flame arrestors should be checked or certified to confirm that they are suitable for their application.

NOTE 2 Equipment and systems of the kind described in c) above should not be confused with those for process control, which do not come within the scope of this standard.

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

1) indication of gas concentration;

2) audible and/or visual alarms;

3) outputs to initiate actions such as process shutdown and automatic safeguard actions, for example process control, ventilation, etc.

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

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

5.2.4 Transportable equipment

Transportable equipment should normally be selected for such purposes as monitoring temporary work areas ("hot work”) and areas where toxic liquids, vapors or gases may be transferred.

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5.2.4.1 Portable equipment

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

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

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

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

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

5.2.4.2 Portability of the equipment

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

5.3 Miscellaneous factors affecting selection of equipment

5.3.1 Electromagnetic immunity

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

5.3.2 Intended location(s) of use

Gas detection equipment normally used in hazardous (classified) areas should be Listed or Labeled. However, this applies to gas detection in normal air which contains approximately 21 % oxygen by volume, or mildly oxygen – depleted air. It does not apply to cases where there is significant oxygen enrichment.

For a description of system safety and equipment response expected under deficient or enriched oxygen conditions, consult the instruction manual, or contact the manufacturer for a recommendation.

6 Behavior of gas releases

6.1 Nature of a release

6.1.1 General

The extent and/or rate of build-up of a toxic atmosphere is mainly affected by the following chemical and physical parameters of the release, some of which are intrinsic properties of the toxic material, others are

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specific to the process or location. For simplicity, the effect of each parameter listed below assumes that the other parameters remain unchanged.

6.1.2 Release rate of gas or vapor

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

The release rate itself depends on other parameters, namely:

a) geometry of the source of release

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

b) release velocity

For a given source of release, the release rate increases with the release velocity. In the case of a product contained within process equipment, the release velocity is related to the process pressure and the geometry of the source of release.

A significant release rate combined with a high velocity will generate a momentum jet which will affect the behavior of the released gas at least in the vicinity of the source.

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

c) concentration

The concentration of toxic vapor or gas in the released mixture influences the release rate.

d) volatility of a toxic liquid

This is related principally to the vapor pressure, and the heat of vaporization. If the vapor pressure is not known, the boiling point and flashpoint can be used as a guide.

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

Some liquids (for example certain halogenated hydrocarbons) do not possess a flashpoint although they are capable of producing an explosive gas atmosphere. In these cases, the equilibrium liquid temperature which corresponds to the saturated concentration at the lower toxic limit should be compared with the relevant maximum liquid temperature.

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

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

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e) liquid temperature

The vapor pressure increases with temperature, thus increasing the release rate due to evaporation.

The temperature of a liquid after it has been released may be increased, for example by a hot surface or by a high ambient temperature.

CAUTION Be aware that if the gas being released is a flammable gas that many of these gases are also toxic in nature with exposure limits well below 10% LFL of the gas. The toxic limits of these gases must be monitored for personnel protection.

6.1.3 Toxic limits

Reference the following documents for guidance on toxic limits:

1) National Institute for Occupational Safety and Health (NIOSH) Pocket Guide to Chemical Hazards, Title 29, Part 1910.1000, Occupational Safety and Health Standards

2) Threshold Limit Values for Chemical Substances in the Work Environment Adopted by the American Conference of Governmental Industrial Hygienists (ACGIH)

3) Documentation for Immediately Dangerous to Life or Health Concentrations (IDLHs) (NIOSH Taft Laboratories)

4) API RP55 Conducting Oil and Gas Producing and Gas Processing Plant Operations Involving Hydrogen Sulfide

Alarm set-points must be determined by requirements of these documents for any toxic gas or vapor under consideration. It may be necessary to seek other regulatory or guidance documents to ensure selection of appropriate alarm limits.

6.1.4 Ventilation

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

6.1.5 Relative density of the released gas or vapor

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

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

NOTE 1 For practical applications, a gas mixture which has a relative density below 0.8 is regarded as being lighter than air (e.g. methane, hydrogen or ammonia). If the relative density of a gas or vapor mixture is above 1.2, it is regarded as being heavier than air. Between these values, both of these possibilities should be considered.

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

6.1.6 Temperature and/or pressure

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

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

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

6.1.7 Other parameters to be considered

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

If there is significant ambient air movement or the release is into enclosed spaces, then the above behavior will be modified as described in subclauses 7.2 and 7.3.

6.1.8 Outdoor sites and open structures

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

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

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6.2 Buildings and enclosures

6.2.1 General

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

6.3 Unventilated buildings and enclosures

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

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

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

6.4 Ventilated buildings and enclosures

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

6.5 Natural ventilation

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

The release of a gas or vapor into a naturally ventilated building or enclosure will tend to result in the formation of a gas/air mixture in a manner similar to that described in 7.3. 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 vapor is released into an enclosure in which natural ventilation produces an upward flow, then the gas/air mixture may extend above, as well as below, the level of the source of release. Conversely, if a lighter than air gas or vapor is released into an enclosure in which ventilation produces a downward flow, then the gas/air mixture may extend below, as well as above, the level of the source of release.

NOTE Further information on natural ventilation is given in ISA-TR12.24.01 (IEC 60079-10) and/or ANSI/NFPA 70.

6.5.1 Mechanical ventilation

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

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 In case of very high gas concentrations (e.g. above 8-hour TWA), or in the area above a toxic liquid with low vapor pressure, an increased ventilation may lead to an increased volume of the explosive atmosphere.

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

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

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

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

6.5.2 Environmental considerations

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

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

7 Design and installation of fixed gas detection systems

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

a) safe evacuation of premises;

b) appropriate fire-fighting and other emergency procedures;

c) removal of hazard;

d) shutdown of process or plant;

e) increasing ventilation.

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

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

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

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7.1 Basic considerations for the installation of fixed systems

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

Three main types of fixed systems are commonly used.

a) Systems consisting of remote sensors connected to the alarm and control equipment by electrical cables

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 may 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 stand-alone equipment should be connected to their associated control and alarm equipment according to the national requirements for installation of electrical equipment. The sensors and any other parts of the system which are located in a hazardous area should incorporate an explosion protection technique as permitted in ANSI/NFPA 70 Article 500-505.

NOTE At excessively high and low temperatures the sensor may be operating outside the temperature range specified by the manufacturer and therefore may no longer comply with its electrical safety certification.

b) Systems consisting of sampling equipment

These systems are used when comparatively static process conditions apply, and rapid response is less important. The main advantage is that they can permit all of the electrical parts of the equipment to be located outside the hazardous area, with only tubes, filters, and other components, inside the area and a suitable flame arrester at the interface. Where a system involving a single detection equipment with timed sequential sampling of a number of sample points is installed, 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.

c) Open path / Line of sight systems

These systems have special requirements, limitations and characteristics that do not come within the scope of this standard, (see also 9.2). 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.

7.2 Location of detection points

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.

But there are other requirements:

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

This determination should consider:

a) the combination of sources of release with propagation effects (Clause 7);

b) whether the sources of release can be inside our outside confining structures, buildings etc.;

c) what can happen at access points such as doorways, windows, tunnels, trenches etc.;

d) local environmental conditions;

e) occupational health and safety;

f) access for maintenance including calibration and verification, and protection of the system against operational hazards of the plant.

The decisions reached on the locations of sensors and sampling points should be recorded in a safety dossier for the plant (refer also 7.5).

7.2.1 General site considerations

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

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

Sensors should also be located in all areas where hazardous accumulations of gas may occur. Such areas may 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 may accumulate in overhead cavities.

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

1) the application of generally accepted empirical rules developed by experts, based on their past experience;

2) on site experimentation to simulate and describe precisely the behavior of the gases. This includes the use of smoke tube tests, anemometer readings or more detailed techniques such as tracer gas analysis;

3) numerical simulation of gas dispersion.

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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 vapor 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.

7.2.2 Environmental conditions

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

7.2.2.1 Adverse weather conditions

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

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

Sensors located in buildings or enclosures are generally not exposed to adverse weather conditions.

7.2.2.2 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 may be operating outside the temperature range specified by the manufacturer, and detection errors and reduced sensor life may occur. In addition, at both excessively high and low temperatures, the equipment may no longer comply with its hazardous area certification and/or stated performance.

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

In general, the positioning of gas detectors directly above sources of heat such as ovens and boilers should be avoided and a suitable position at an adequate height away from the source of heat should be chosen.

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In tropical and subtropical applications, external sensors and equipment should be shielded from direct sunlight, as this can raise equipment temperatures above 65 °C even with ambient temperatures around 40 °C. The general requirements for hazardous area certification is 40 °C and the requirement for performance certification per ANSI/ISA-92.00.01 and ANSI/ISA-92.00.04 is 55 °C, unless otherwise specified on the certificate.

7.2.2.3 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.

7.2.2.4 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, Hydrogen Sulphide (H_2S) etc.). Particular care should be taken to protect wiring (and other components made of copper or brass) if ammonia can be present, as it can cause severe corrosion and electrical failures.

7.2.2.5 Mechanical protection

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

7.2.2.6 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.

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

7.2.2.7 Hosing down

The practice of "hosing down" a plant may cause severe degradation of gas sensors and contaminate sampling lines. It should, therefore, be avoided if possible. If it cannot be avoided, the sensors should be protected against this, without impeding the free flow of air around them. This can be a complex problem. Follow the manufacturer’s maintenance procedures indicated for such conditions.

7.2.2.8 Airborne and other contaminants

Sensors should not be exposed to airborne contaminants which may 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 may require regular cleaning or similar maintenance. Sample extraction and special filtration may be required in extreme cases.

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

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

There are particular problems where a vapor 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 may be to heat the components that come into contact with the sample.

7.3 Access for calibration and maintenance

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

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

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

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7.4 Additional considerations for sample lines

Sampling lines are usually permanently installed in fixed installations. Even if they are made of a flexible plastic material they will usually be less flexible and harder to install than cabling.

Consideration should be made at the time of installation that they may need to be replaced in the future, for instance if they become badly contaminated or damaged. Joints need to be accessible.

Sample lines should be as short as possible since the response time is determined by the overall length. Composition of the line selected must be compatible with the gas being sampled, where minimum absorption of the gas will occur.

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

Filters will increase the response time.

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

The flow rate through the sampling line should be monitored.

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

Where water condensation can occur it may block the sampling line. Water traps may 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 (e.g. air conditioned areas in hot humid climates). Alternatively, the line may 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 vapor will permit it to re-evaporate, giving incorrectly high readings. To minimize this effect, heating of the sampling line may be necessary. In hazardous areas if this heating system is electrical it shall comply with the relevant regulations and standards. Steam or hot water trace heating may be an option.

7.5 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 (refer to 7.5).

NOTE Reference may be made ANSI/ISA-60079-29-2.

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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 vapor/gas sources (for example density, pressure, amount, source temperature, and distance) need to be assessed;

c) chemical and physical data of the potential gases/vapors present;

d) liquids with low volatility need sensors near the potential source of release (and low alarm or action points);

e) nature and concentrations of gas releases likely (for example high pressure jet, slow leaks, spillage of liquids);

f) presence of cavities and jets;

g) topography of the site;

h) air movements;

    1) indoors: natural ventilation, mechanical ventilation, convection,

    2) outdoors: wind speed and direction,

i) temperature effects;

j) environmental conditions of the plant;

k) location and number of personnel in the area;

l) location of potential sources of ignition;

m) structural arrangements (such as walls, troughs or partitions) which could allow vapor/gas to ac

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.

7.6 Installation of sensors

For the reliable operation of a fixed gas detection system 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 may be specified by the manufacturer.

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

Any potential 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 be deleterious to the sensors.

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

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

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7.7 Integrity and safety of fixed systems

7.7.1 General

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

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

Additional measures to preserve safety may include:

a) signaling 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) establish a thorough maintenance procedure based on manufacturer's instructions taking facility conditions into account.

7.7.2 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.

7.7.3 Protection against loss of main power supply

Protection against loss of the main power supply should include:

a) main power supply

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

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

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

b) emergency power supply

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

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

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It is strongly recommended that for indication of power and/or equipment failure, contacts are used which are open when power is applied to the system and closed in the non-powered state allowing positive indication of failed system (fail-safe).

7.8 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 vapors in the system, so as 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.

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7.9 Commissioning

7.9.1 Inspection

The complete gas detection system including all ancillary equipment should be inspected prior to use to ensure that the design and installation has been carried out in a satisfactory manner, and that, where appropriate, the methods, materials and components used are in accordance with ANSI/NFPA 70. Among the items to be inspected are the following:

a) confirm electrical connections are properly tightened;

b) check for sample-line leaks and proper flow;

c) check for clogged or dirty flame-arresting systems;

d) check the battery voltage and/or battery condition and make any required adjustments or battery replacements (according to the instruction manual);

e) perform a test of the failure (malfunction) circuit(s).

A check should be made at this time to confirm that a full dossier of operating instructions, plans and records for the complete system have been supplied. This should have details of all sensing points (refer to 7.5). The instructions should include details on use, testing, calibration and operation, and should include all manufacturers' instructions (refer to 7.10).

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 (e.g. maintenance) signal to prevent the output from being mistaken for a normal measurement.

Where a number of gases are likely to be present, reference should be made to the additional precautions described in 4.3.2.1 and 6.1.7.

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 false alarm signals.

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

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

Refer to documents listed in 6.1.3 Toxic Limits to determine appropriate selection of alarm set points. End user policies or local regulations may also provide requirements for the alarm set points.

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7.10 Operating instructions, plans and records

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

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

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

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

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

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

The detection system should be frequently reinspected by a competent person. The inspection should be in accordance with the instructions of the manufacturer and the specific requirements of the application. A visual inspection of all units of the gas detection system should be carried out and the test and alarm functions should be checked. Special attention should be taken to look for contamination (e.g. dust or soil) and condensation of water or solvents in sampling systems and at the sensor locations.

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

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

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

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

8 Use of portable and transportable toxic gas detection equipment

8.1 General

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In Clause 8 it can be seen that there are many skills required in designing and creating an installation for fixed gas detection equipment.

Each time a portable or transportable gas detection equipment is used, its user is also essentially carrying out many of the same important functions in creating a temporary installation. However, the user will generally not have all the skills.

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

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

a) To give personnel required to use portable or transportable gas detection equipment proper training in its use, which would include Clauses 4 and 10, the rest of this clause, the relevant part of Clause 5 or preferably Annex A, and to train on and provide ready access to the operating instructions of the particular equipment.

b) To adopt the minimalist approach described as "read and run" in 8.3.9, following basic training on the particular equipment and on any personal safety precautions relating to the particular application and any toxicity. Checking, calibration, etc. should then be done by others.

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

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

Transportable equipment is intended for use for temporary area monitoring in locations where there is a probability of generating potentially toxic gas or vapor mixtures, for example during the loading or unloading of fuel or chemical tankers or where temporary "hot work" (in connection with maintenance activities) may be in progress in classified hazardous areas under the authority of a gas-free certificate.

Transportable equipment is not intended to be hand carried for long periods of time, but is intended to be in place for periods of hours or more.

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

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

8.2 Initial and periodic check procedures for portable and transportable instrumentation

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

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

8.2.1 Inspection and field-check (response check)

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

NOTE 1 The instruction manual of portable equipment complying with ANSI/ISA-92.00.01 is required in Subclause 4.4 of that standard to provide a method for performing a functional check with gas before each day of use.

NOTE 2 In critical cases where a permit to work is given as the result of a gas test, it is recommended that a response check is performed afterwards, and that the result of both the gas test and the response check are logged.

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A simple sequence of inspections may include the following:

1) checking the battery voltage and/or battery condition;

2) allowing adequate warm-up time;

3) checking for sample-line leaks and proper flow in aspirated equipment;

4) checking that a zero reading is displayed when operated in clean air (see note below);

5) performing a response check.

The last two of these may be performed as follows:

Place the detector head (integral or remote) or the sampling line in an atmosphere free of toxic gas, aspirate a large enough sample to purge the lines (applicable only to equipment with sampling lines). If a significant deviation from zero is observed (but see note below), the equipment should be recalibrated (see 8.2.2). Some instruments have an automatic zero check which will do this adjustment.

NOTE 3 Although there should be no measurable amount of toxic gases in clean air, and therefore a toxic gas sensor should read zero, this is not necessarily true for other sensors that may be incorporated in the same instrument: Oxygen sensors should read 20.8 or 20.9 % v/v under these conditions. There are approximately 360 parts per million of carbon dioxide (more in heavily built-up areas) which should give appropriate readings (e.g. 0.03 or 0.04 % v/v CO_2). Also in built up areas, there may be detectable amounts of CO.

The response (sensitivity) of the equipment should be checked using the field calibration kit recommended by the manufacturer and performed with a known gas mixture which will give a response from all the sensors present. The user should know or should be instructed what reading(s) should be obtained. If the test results are not within ±10 % of the anticipated result, the equipment should be recalibrated (see 8.2.2).

NOTE 4 Very reactive gases like fluorine, hydrogen chloride or ozone are not suitable to be used within calibration gas mixtures for field checks.

For alarm-only equipment, a test gas concentration should be applied which is equal to 5 % LFL above the highest alarm set point of the equipment. All alarms should actuate during this test. If an equipment fails this procedure, and suggested corrective action does not solve the problem, the equipment should be recalibrated (see 8.2.2).

8.2.2 Routine checks and recalibration

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

a) resetting of the mechanical zero of analogue meters;

b) checking the tightness of all electrical connections (remote detector head, power supply etc.);

c) allowing adequate warm-up time;

d) checking for sample-line leaks and proper flow;

e) checking for clogged or dirty flame-arresting systems;

f) checking the battery voltage and/or battery condition and making any required adjustments or battery replacements;

g) performing a test of the failure (malfunction) circuit(s);

h) testing the alarm circuits;

i) recalibrating by adjusting to a zero reading when operated in clean air and the correct value when a known calibration gas is applied. This may be done as follows:

Place the detector head (integral or remote) or the sampling line in an atmosphere free of toxic gas, aspirate a large enough sample to purge the lines (applicable only to equipment with sampling lines). If a deviation from zero (see note in 8.2.1 for other gases) is observed it should be recorded and then adjusted to zero. Some equipment have an automatic zero check which will do this adjustment.

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

NOTE 1 For catalytic sensors the mixture should contain at least 10 % by volume of oxygen. In some modern multi- gas equipment the gas specified by the manufacturer may have a known oxygen concentration above this value, and known concentrations of some toxic gases. This is used to simultaneously recalibrate all its sensors.

NOTE 2 Very reactive gases like fluorine, hydrogen chloride or ozone are not suitable to be used within calibration gas mixtures for field checks.

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

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

8.2.3 Maintenance and recalibration

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

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

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

Defective units should be either:

– returned to the manufacturer; or

– returned to a repair agent authorized by the manufacturer; or

– repaired in special workshop set up by the user for gas detector maintenance. The results of maintenance and recalibration should be recorded in the dossier.

8.3 Guidance on the use of portable and transportable equipment

8.3.1 Electrical safety in hazardous atmospheres

Portable and transportable equipment should have a type of electrical protection appropriate for the zone (hazardous (Classified) location) in all the areas in which it is intended to be used.

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8.3.2 Safety of personnel

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

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

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

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

Switch on the equipment, allow it to warm up as necessary, and perform any fresh air checks (see e.g. 8.2.1) in a safe area but as close as practicable to the ambient conditions in the area to be monitored.

When entering the potentially hazardous area the user should frequently observe the readings on the equipment and take into consideration that the extent of the potentially hazardous area may be larger than expected. The user could be entering an already dangerous situation and may need all the warning they can get.

8.3.3 Spot tests and sampling

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

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

NOTE Only sample lines recommended by the manufacturer should be used (see notes on adsorption and chemical reactions in 7.4).

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

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

Sample 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.

8.3.4 Sampling above liquids

When sampling vapor above a liquid, care should be taken to avoid the sample line or sensor from coming into contact with the liquid, since this may block the gas entry to the equipment, could damage the sampling system or sensor, and cause erroneous readings. Use a hydrophobic filter or equivalent where

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there is danger of drawing water into the detector. A probe with side entry and a solid tip can help to avoid drawing liquid in.

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

8.3.5 Avoidance of condensation

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

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

8.3.6 Poisoning of sensors

If the portable equipment is of the multi-gas type containing sensors for the detection of toxic gases at low concentrations then calibration with some toxic gases, typically hydrogen sulphide, ammonia and chlorine, may 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 must be checked at frequent intervals (see 8.2.1).

8.3.7 Changes of temperature

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

8.3.8 Accidental damage

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

8.3.9 Minimalist operation, the “Read and run” concept

The safety margins are increased if small changes in readings are observed, rather than only relying on alarms that are always set at a higher level.

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

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

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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) On going 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.

e) Then inform the responsible person, who may then carry out a proper survey by experienced personnel, taking proper precautions.

9 Training of operational personnel

9.1 General

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

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

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

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

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

Periodic refresher training is strongly recommended.

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

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

9.2 General training – Basic limitations and safety

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

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Certain minimum information on limitations should always include:

a) Toxic (toxic) gas equipment will only detect gases and vapors that are present in the vicinity of the detector (or in the line of sight of open path equipment).

b) It will only detect those vapors that do not condense at the temperature of the detector or its sampling equipment (where applicable).

c) Where liquid flashpoints are well above ambient temperatures vapors can only exist at low percentages of LFL.

d) Toxic gas equipment will not detect toxic liquids as such, or toxic mists, dusts, or fibres.

e) Many types of toxic gas equipment have varying sensitivity to a whole range of gases.

f) If the gas detected is not the gas on which the equipment is calibrated, the reading will indicate upscale, but may not be correct.

g) Erratic indications may indicate equipment malfunction or some atmospheric disturbance.

h) Where doubt exists, a check should be made with a second equipment and/or the equipment should be rechecked under controlled conditions before its continued use.

i) The occasional or continuous presence of low concentrations of the gas of interest will produce indications that could be mistaken for zero drifts. In case of doubt, the equipment should be rechecked using clean air.

j) If off-scale readings in either direction are observed, It should be assumed that a potentially explosive atmosphere is present until proven otherwise (e.g. by checking with a second equipment, applying clean air and then rechecking, etc.).

k) Some toxic gases and all vapors (except water) are toxic at low levels of concentration. The potential toxicity should be known, and necessary precautions taken.

l) In confined spaces there may be oxygen deficiency, which in turn might be due to toxic substances. Confined space entry is a specialized operation and requires specialist training.

m) If probing or sampling via a tube from confined spaces, a severe oxygen deficiency can cause the more common types of toxic (toxic) gas equipment to misread.

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9.3 Operator training

In the simplest case for users of portable equipment, there is the training for “Read and run” operations (see 8.3.9). This, however, requires that the person directing the operator is sufficiently well trained to be responsible for the safety of the operator in the particular circumstances under which the operator will, or could possibly, be working.

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

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

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

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

9.4 Maintenance training

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

10 Maintenance, routine procedures and general administrative control

10.1 General

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

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

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

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

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

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

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

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