

Safety at Work Series



Authorised Gas Tester (AGT)

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Authorised Gas Tester (AGT)

This self-paced course is designed for persons who are Authorised Gas Testers. It must be studied in conjunction with the operators manual for the specific Atmospheric testing unit that you are intending to use.

Elements of this course include

- common chemical asphyxiants, including hydrocarbons, carbon dioxide, carbon monoxide, hydrogen cyanide, and hydrogen sulphide
- common irritants and corrosives, including chlorine, ammonia and acid bases
- common flammable gases, including acetylene, petroleum, methane,
- explosive range, upper and lower explosive limits
- exposure standards (time weighted average, short term exposure limits, peak limitation values, examination of toxic effect at the level of a range of flammable gases)
- conditions under which atmospheres become hazardous
- units of measurement used to express concentration of atmospheric contaminants

If you would like a Certificate of Completion for this course the cost is \$50.00. Frontline Safety & Training recommends that everyone completes this course. There is no need to pay for the certificate unless you require this for your resume.

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1. NORMAL ATMOSPHERE

At the completion of this section, the participant must be able to explain the composition of atmospheric air as well as being able to outline the respiratory process

1.1 COMPOSITION OF AIR

The air we breathe is a mixture of several gases. Atmospheric air always contains varying quantities of water vapour, usually (0-5%) of the total volume, depending on the temperature in the air.

If the water vapour is removed, the remaining dry air has the following composition by volume:

NITROGEN (N)	78.09%
OXYGEN (O₂)	20.95%
CARBON DIOXIDE (CO₂)	0.04%
OTHER GASES	0.92%
(Argon, Neon, Helium, Krypton, Methane, Hydrogen, Nitrus oxide, Zenon)	

Clean air is colourless, odourless and tasteless.

NITROGEN (N) is a chemically inactive gas that under normal circumstances does not affect the process of respiration. However in high concentrations NITROGEN acts as a simple asphyxiant (suffocation). Symptoms of asphyxiation include rapid gasping respiration, rapid fatigue and vomiting. Exposure to high concentrations may lead to loss of consciousness and death.

OXYGEN (O₂) is the gas on which life depends. Nothing can burn or be combusted in the absence of oxygen. On the other hand, oxygen cannot burn in the absence of combustible substances.

Normal air contains 21% oxygen. Pure oxygen is classified as a poisonous gas. Long exposure and at high concentrations can have toxic effects.

Symptoms of oxygen toxicity include chest tightness, burning pain and coughing spasms. Other symptoms are nausea, dizziness, hypothermia, fainting and convulsions. Exposures to high levels of oxygen are unusual. However exposures to low levels of oxygen are common in the workplace.

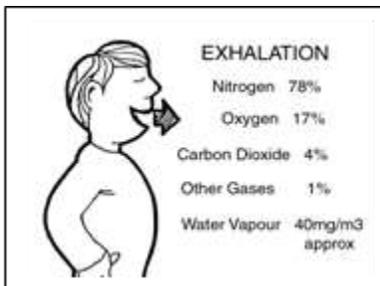
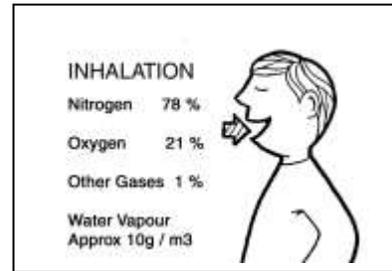
Symptoms of low oxygen level are rapid pulse and breath, heavy to breathe. Continuous exposure to low level of oxygen can cause unconsciousness and death.

1.2 BREATHING PROCESS

What actually happens when we breathe?

Ventilation is composed of two phases, one that brings air into the lungs, **INHALATION** and one that lets air out into the environment, **EXHALATION**.

INHALATION gives the lung capillaries an opportunity to take up **OXYGEN**.



EXHALATION gives the lung capillaries an opportunity to give up much of their **CARBON DIOXIDE**. This exchange of gas is almost instantaneous.

CARBON DIOXIDE is the natural stimulant to breathing and the level of carbon dioxide tells the breathing centre in the brain when we need to breath.

However if the Carbon Dioxide level in the air we breathe is for example 5%, the breathing becomes very laboured and if it raises to 10% you may become unconscious.

OXYGEN is a colourless, scentless and tasteless gas that is essential to man, animal and vegetation.

2. OCCUPATIONAL EXPOSURE LIMITS

At the completion of this section the participant must be able to explain where to obtain information in regard to exposure standards. He/she must also be able to explain the meaning of TWA, STEL, Peak Limitation and IDLH.

2.1 NATIONAL EXPOSURE STANDARDS

Occupational exposure limits are established to set limits which, according to current knowledge, should neither impair the health of, nor cause undue discomfort, to nearly all workers. However, the exposure standards are not fine dividing lines between satisfactory and unsatisfactory working conditions.

“Exposure standard” means an airborne concentration of a particular substance in the worker’s breathing zone exposure to which, according to the current knowledge, should not cause adverse health effects nor cause undue discomfort to nearly all workers.

The WA Mines Inspection Regulations as well as the WA Occupational Health and Safety Regulations require compliance with the “National Standards for Atmospheric Contaminants in the Occupational Environment”, as declared by the National Occupational Health and Safety Commission of Australia.

2.1.1 TIME WEIGHTED AVERAGE (TWA)

Time weighted average is the concentration for a normal 8 hour work day or a five (5)-day working week, to which most workers can be exposed repeatedly, day after day, without adverse effect. As an example the TWA for Sulphur Dioxide (H₂S) is 10 parts per million (ppm) for 8 hours.

2.1.2 SHORT TERM EXPOSURE LIMIT (STEL)

Is the maximum concentration to which workers can be exposed for a period up to 15 minutes continuously without negative effect. A worker should not be exposed to more than 4 such periods during a working day. The STEL for H₂S is 15 ppm

2.1.3 PEAK LIMITATION

Some substances can act very quickly. In these cases a peak limit has been allocated. This means the maximum concentration that a worker can be exposed to momentarily or instantaneously. Under all circumstances not for longer than 15 minutes. Hydrogen Cyanide has a peak limitation of 10ppm.

2.1.4 IDLH (IMMEDIATELY DANGEROUS TO LIFE AND HEALTH)

This is the level where exposure represents an immediate danger to life and health.

Exposure standards:

- Are action levels
- Provide acceptable/unacceptable levels
- Are not necessary safe or unsafe
- Are not to be used as a fine line between acceptable/unacceptable or safe/unsafe

The NATIONAL EXPOSURE STANDARDS FOR ATMOSPHERIC CONTAMINANTS IN THE OCCUPATIONAL ENVIRONMENT (Works Safe Australia National Exposure Standards [NOHSC:1003(1995)]) will give details of TWA, STEL and PEAK limitations for substances.

3. HAZARDS & RISKS

After completion of this section, the participant must be able to explain the effects on the body of exposure to air of different composition than normal air e.g an atmosphere that is not suitable for breathing.

The hazard in the atmosphere can vary from being **toxic or oxygen deficient to being flammable or explosive**. It is imperative to fully understand the difference between the hazards, what type of hazard can be present and the most likely situations to appear.

3.1 CONTAMINATED AIR

Inhalation is by far the most common route by which hazardous substances gain entry to the body.

3.1.1 DUST

Solid air-borne particles. Large amounts of dust are formed when solid materials are broken down. Dust can be created by performing such tasks as drilling, sawing, milling, polishing, blasting and similar operations. Exposure to dust is also possible when handling chemicals in powder form. Dust usually causes irritation to the respiratory tract (coughing, sneezing etc.), but may also contain harmful substances, such as asbestos, silica, lead and many others. These materials can cause serious disabilities and even death.

3.1.2 AEROSOLS

Tiny liquid droplets usually created by spraying operations (spray painting, pesticide spraying, surface treating etc.). The spray may contain a combination of several hazardous ingredients. The consequences can be serious and permanent.

3.1.3 SMOKE & FUME

Smoke is the result of incomplete combustion. Fumes occur when solids are heated. Welding and smelting are areas where fumes occur. Smoke can suffocate and some fumes are known to cause serious long-term health effects. Occupational asthma is one such disease.

3.1.4 GAS & VAPOUR

Gases are substances that become airborne at room temperature. Vapours are substances that evaporate from liquid or solid. Toxic compounds may also be formed when gases are heated or come in contact with other materials. Failure to protect against gases and fumes can cause serious respiratory disease or death.

3.1.5. TOXIC GASES

Toxic gases are compounds or elements that pose a threat to human life – react in the body in a poisonous fashion. Toxic gases can enter the body by being inhaled, ingested, injected or absorbed through the skin. Toxic gases are often colourless and odourless making them a serious threat in the working environment.

Two very common toxic gases are: Carbon Monoxide (CO) and Hydrogen Sulphide (H₂S).

Toxic gases can have a chronic (long term) effect and / or an acute effect (immediate).

CHRONICALLY TOXIC GASES

- Prolonged exposure
- Effect on haemoglobin
- Flu-like symptoms (headache, dizziness)
- Medical effect may not be felt for many years
- Carbon Monoxide (CO) most common

ACUTELY TOXIC GASES

- Inhibit cell respiration
- Effect on enzymes
- Shut down lungs and other organs
- Can cause death
- Hydrogen Sulphide (H₂S) most common

With the above in mind it is important to be able to measure toxic gases in low concentrations. Therefore toxic gases are measured in PPM. For example, a gas detector reading 10ppm of hydrogen sulphide (H₂S) means that the atmosphere under test contains 10 parts of H₂S and 999,990 parts of air.

3.2 CARBON MONOXIDE

Carbon Monoxide (CO) is colourless, odourless and a by-product of incomplete combustion. CO is flammable and has an Lower Explosive Limit (LEL) of 12.5%. CO is very toxic it can be absorbed 200-300 times faster than oxygen by the haemoglobin

3.2.1 Harmful effects of Carbon Monoxide (CO)

PPM	EFFECTS AND SYMPTOMS
30	Permissible Exposure Level (TWA)
400	Maximum Short Term Exposure Level (STEL)
600	Severe headache and discomfort
1000-1500	Confusion, headache, nausea, tendency to stagger
1200	IDLH
2000	Unconsciousness
4000	Death within 1 hour

3.3 SULPHUR DIOXIDE

SO₂ is a colourless gas with an irritating pungent odour. SO₂ is a non-flammable gas. SO₂ will combine with water to form sulphurous acid (H₂SO₃) "Acid Rain".

3.3.1 Harmful Effects of Sulphur Dioxide (SO₂)

PPM	EFFECTS AND SYMPTOMS
0.3-1	Initial detectable by taste
2	Permissible exposure level TWA
5	Maximum Short Term Exposure Level (STEL)
20	Irritation of nose, throat and eyes
100	Maximum exposure for 30 mins

3.4 HYDROGEN SULPHIDE

H₂S is colourless gas with a rotten egg smell. H₂S is flammable with an LEL level of 4.0%
 H₂S is extremely toxic. It appears naturally from decomposition, reacts with enzymes in the blood and inhibits cell respiration.

3.4.1 Harmful Effects of Hydrogen Sulphide (H₂S)

PPM	EFFECTS AND SYMPTOMS
0.13	Minimal perceptible odour
4.6	Easily detectable, moderate odour
10	Permissible exposure level TWA Beginning eye irritation
15	Maximum Short Term Exposure Level (STEL)
27.0	Strong, unpleasant odour, but not intolerable
100	Coughing, eye irritation, loss of smell after 2-15 minutes
200-300	Marked conjunctivitis (eye inflammation) and respiratory tract irritation
300-500	Possible loss of consciousness
500-700	Loss of consciousness and possible death in 30 minutes
700-1000	Rapid unconsciousness, cessation (stopping) of respiration and death
1000-1500	Unconsciousness at once, with early cessation of respiration and death within a few minutes. Death may occur even if individual is removed to fresh air

3.5 AMMONIA

NH₃ is colourless gas with a suffocating odour. NH₃ is flammable with an LEL level of 15%. However it is difficult to burn. NH₃ is extremely toxic.

3.5.1 Harmful Effects of Ammonia (NH₃)

PPM	EFFECTS AND SYMPTOMS
0-25	Minor irritation of eyes and respiratory tract
25	Permissible exposure level TWA
35	Maximum Short Term Exposure Level (STEL)
50-100	Swelling of eye lids, conjunctivitis, vomiting, irritation of the throat
100-600	Very dangerous, potential deadly from prolonged exposure

3.6 OXYGEN DEFICIENCY

Oxygen deficiency can occur in confined spaces whenever the normal percentage of oxygen is too low. It can also be caused by a chemical reaction, fire or when gas displaces oxygen. The most common oxygen deficient situation occur in confined spaces.

Oxygen levels can and will change under certain circumstances. The Oxygen level may be reduced by:

- **DISPLACEMENT or Dilution** with other gases e.g. Nitrogen, Hydrogen, Propane etc.
- **REACTION** with other substances e.g. oxidation when rust is formed
- **COMBUSTION** fire, welding etc.
- **Absorption of** other substances e.g. water, people, bacterial action

3.6.1 Physiological effects in various oxygen levels

OXYGEN CONCENTRATION	PHYSIOLOGICAL EFFECTS
21%	Normal concentration
18 %	Effecting concentration
16 %	Instability & confusion
12-16%	Increased breathing and pulse
8-12%	Lack of co-ordination, fatigue
6-8%	Inability to move, convulsion
4-6%	Loss of consciousness
2-4%	Immediate loss of consciousness
0-2%	Immediate coma with brain damage within a few minutes

4. HAZARDOUS AREAS

At the completion of this section, the participant should be able to understand classification of hazardous areas. The learner must also be able to explain the properties of flammable atmospheres as well as explosive limits.

Many gases, vapours and dusts that are generated, processed, handled and stored in industry are combustible. When ignited they may burn rapidly and with considerable explosive force if mixed with air in the appropriate proportions. Areas where gases and vapours, filings and fibres occur in dangerous quantities are classified as hazardous.

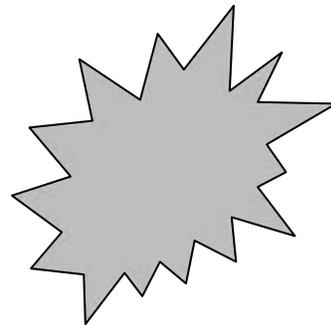
4.1 HAZARDOUS AREAS

Areas that are deemed to be hazardous areas are classified as Zone 0, 1 or 2.

- ZONE 0** an area where an explosive gas atmosphere is present continuously, or is present for long periods

- ZONE 1** an area where an explosive gas atmosphere is likely to occur in normal operation

- ZONE 2** an area where an explosive gas atmosphere is not likely to occur in normal operation and if it does occur it will exist only for a short period



Details of Classification of hazardous areas can be found in Australian Standards:
AS 2430.1-1987 **AS2430.21986** **AS/NZS 2430.3.1-9:1997**

4.2 IGNITION RISK AREA CLASSIFICATION

IGNITION RISK AREAS are classified according to the type of hazardous material present. This rating system is primarily used to determine the type of electrical equipment that can be safely used in **IGNITION RISK AREAS**

The hazard classes are:

- Class I** Flammable gases or vapours
- Class II** Combustible dust

4.3 HOT WORK

Hot work is commonly divided into to two categories namely - **HIGH RISK** and **LOW RISK**.

4.3.1 HIGH RISK HOT WORK

High Risk Hot Work activities are high energy activities that have a high potential to ignite materials or gases and include work such as:

- Oxy cutting, welding & heating
- Arc welding
- Soldering using a naked flame
- Grinding
- Dry abrasive blasting

4.3.2 LOW RISK HOT WORK

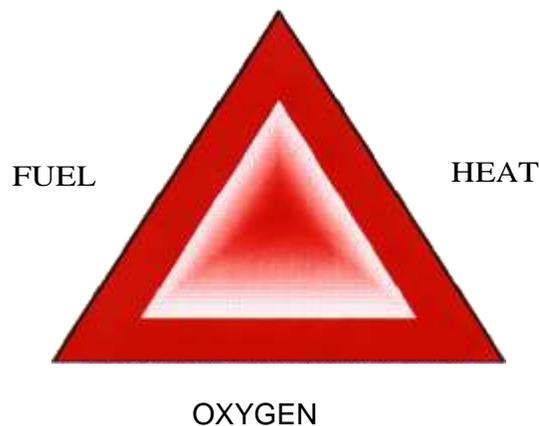
Low Risk Hot Work activities are activities that still have the potential to ignite flammable material and gases and includes work such as:

- Wet abrasive blasting
- Spray painting
- Metal chipping using a needle gun
- Use of electrical power tools

4.4 FIRE & EXPLOSION

Simply put, a FIRE or EXPLOSION is a chemical reaction that is taking place (rapid oxidation) which produces energy in the form of heat and most times light. At this stage it must be recognized that flames will not necessarily be visual in all situations where we have a fire. An example, flames from hydrogen are not visual.

This chemical reaction requires three (3) components: **FUEL, OXYGEN & HEAT**. These components are usually shown in the form of the **FIRE TRIANGLE**.



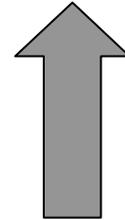
If the triangle should be broken, then the fire will be extinguished.

4.5 PROPERTIES OF FLAMMABLE ATMOSPHERES

Before an explosion can occur (reaction) there must be a mixture of a flammable gas or vapour (fuel molecules) with air. A mixture of flammable gas or vapour with air or oxygen will only burn if the concentration of the combustible fraction is within certain limits and an ignition source is present. The essential difference between gas burning and a gas explosion is simply the rate at which oxidation of the fuel occurs. If no oxygen is contained in the molecules of the combustible material, no burning can normally take place. The very rapid oxidation that characterises an explosion is only possible if sufficient oxygen is available to react with all the fuel. These limits are referred to as **EXPLOSIVE LIMITS**.

4.5.1 HIGH CONCENTRATION OF FUEL

If we attempt to initiate a reaction by applying an ignition source where more fuel molecules exist than oxygen molecules, the heat applied is quickly dissipated amongst all the fuel molecules. Therefore a HIGH FUEL CONCENTRATION would be a barrier to ignition and ignition impossible.

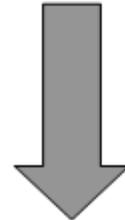


Oxygen levels above 23% can become explosive when in contact with hydrocarbons.

4.5.2 LOW CONCENTRATION OF FUEL

Where there is a low fuel concentration (low number of fuel molecules) in an air mixture, the fuel molecules are too far apart to absorb the heat (ignition source) being applied to continue the reaction and cause actual ignition.

It should be noted that a few gases at their upper explosive limit (UEL), under certain circumstances, can explode even if not mixed with air. This is possible either because the gas molecules contain oxygen which may be liberated to support combustion or because the molecular structure is unstable and may decompose explosively if, for example, it is stored under pressure or comes into contact with a triggering agent, Acetylene is an example of this



4.6 EXPLOSIVE LIMITS

For flammable gases that require air to support the combustion process we can define in terms of explosive limits.

LEL = LOWER EXPLOSIVE LIMIT

The LEL is the minimum concentration of flammable gas/vapour mixed with air, which could form an explosive mixture and be ignited. Gas concentrations below LEL are said to be too lean to burn.

UEL = UPPER EXPLOSIVE LIMIT

The UEL is the highest concentration of flammable gas/vapour mixed with air, which could form an explosive mixture and be ignited. Gas concentrations above UEL are said to be too rich to burn.

C= STOICHIOMETRIC COMPOSITION

The stoichiometric composition is the composition, which is readily ignited, therefore a limited amount of energy is needed to ignite the concentration

4.7 EXPLOSIVE (FLAMMABLE) MIXTURES

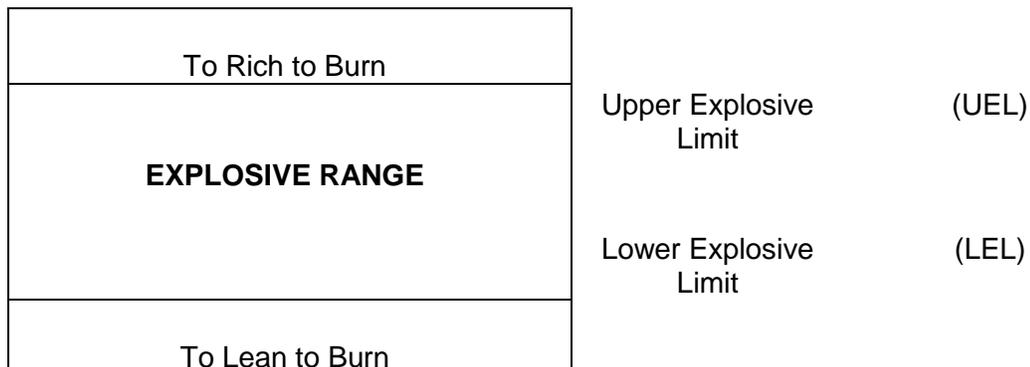
Explosive (Flammable) mixtures in air are measured in %. When using a combustible gas detection meter, measurements are given in % of the flammable gas.

For example, the LEL for methane is 5%. This means the atmosphere under test is made up from 5 parts methane and 95 parts of air. If the UEL is 14% this means that the atmosphere under test is made up from 14 parts methane and 86 parts of air. It is necessary to understand exactly what the meter is actually measuring. Most instruments measure up to the lower limit, i.e. 100 on the meter. If the meter rises to 100 and stays there it is an indication that the vapour concentration is at the LEL of that gas or is in the flammable range

4.7.1 Explosive limits of specified flammable gases

FLAMMABLE GAS OR VAPOUR	LEL (% by volume)	UEL (% by volume)
Hydrogen	4	75
Methane or Natural Gas	4.9	15
Ethane	3	15
Propane	2	9.5
Butane	1.8	8.4
LPG	2	10
Petrol Vapour	1.4	7.6
H ₂ S	4.3	46
Acetylene	2.5	85

In order to detect combustible liquids the vapour pressure must be sufficient to produce concentration within the range of detection. Vapour pressure increases with temperature and decreases with molecular weight.



5. OTHER PROPERTIES

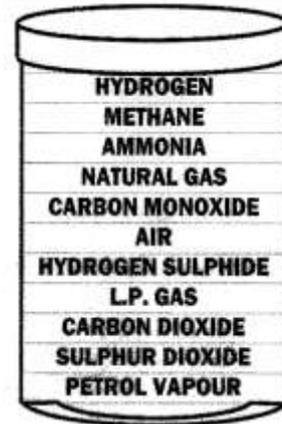
At the completion of this section the participant must be able to explain other properties of gases that can have an influence on gas detection and interpretation of results.

To be able to correctly carry out gas detection and to interpret the result, there are some additional facts that need to be understood.

5.1 RELATIVE VAPOUR DENSITY

Density means a measure being the ratio of mass to volume. The relative density of air at atmospheric pressure is 1 (one) with a molecular weight of 29. Gases and vapours can have a density less than 1, i.e. lighter than air. This means that gas that is lighter than air will rise (go up). Gases can also have a density greater than 1, i.e. heavier than air. This means that these gases are heavier than air and will tend to sink and stay at a very low level.

From the above it can be established that vapours move from place to place under the influence of gravity and this must be considered when carrying out testing. It is possible to calculate the weight of gases and compare with air.



Gases and vapours can be heavier or lighter than air. As per the below examples in the table.

Substance	Molecular Weight	Heavier or Lighter
Atmosphere	29	-
H ₂ S	34	H
NH ₃	17	L
SO ₂	64	H
C ₇ H ₈	92	H
CO ₂	44	H
Ch ₄ (Methane)	16	L
CO	28	L (slightly)

5.2 VAPOUR PRESSURE

The pressure exerted by escaping vapour at the point of equilibrium (state of balance) is called vapour pressure and is measured in psi or kPa. The vapour pressure depends only on temperature. The vapour pressure will increase by a factor of 1.5 for each 10°C rise. As a consequence very small rises in temperature can cause a big increase in the quantity of vapour.

5.3 FLASH POINT

Flashpoint is the lowest liquid temperature at which liquid gives off vapours in sufficient quantity to form an ignitable vapour and air mixture.

Aviation fuel has a flash point of 37.8°C. Methane has no flash point as it can be ignited at normal temperatures and pressures.

Specific test methods are set out in the Australian Dangerous Goods Code for testing and classifying flash points.

5.4 IGNITION TEMPERATURE (AUTO IGNITION).

Auto ignition means the temperature required initiating a substance in the absence of a spark or a flame or other ignition source. Methane has an auto ignition temperature of 590°C.

6. MEASUREMENTS

After completion of this section the participant must have a complete understanding of measurements that are used with gas detection. He/she should also be able to convert from one measurement to another.

Oxygen or toxic gases as well as LEL are usually presented on gas detection equipment on a numerical scale. The measurement is either given in:

% (percent) = parts per hundred

(in percent, the sum of the parts always add to 100)

PPM = parts per million

(In ppm, the sum of the parts always adds to 1 000 000)

mg/m³ = milligram per million

(In mg/m³, the sum of the parts always adds to 1 000 000)

Both percent (%) and PPM can be used to describe parts in either volume or mass. Volume is the most commonly used in gas testing.

‘Milligram per Cubic Metre’ is the unit used where relative weight in a given volume is a more meaningful measure of an atmospheric constituent.

6.1 EXPLOSIVE LIMITS

The explosive limits are usually expressed as a percentage (%) of volume of the flammable gas that must be present in air. It should be noted that the UEL for a few gases in “100” i.e. the gas can, under certain circumstances, explode even if not mixed with air. This is possible either because the gas

molecules contain oxygen which may be liberated to support combustion or because the molecular structure is unstable and may decompose explosively if, for example, it is stored under pressure or comes into contact with a triggering agent. Acetylene is an example of gas in this letter category.

6.2 OXYGEN

Oxygen is measured in %. Thus 19% oxygen in air means that the atmosphere under test contains 19 parts of oxygen 81 parts of other gases, predominantly nitrogen.

6.3 TOXIC GASES & VAPOURS

With Oxygen and flammable gases, an appreciation is obtained of the concentration using expression of % (percentage).

It is important to be able to measure toxic gases in low concentrations. Most of today's common gas detection equipment will give toxic gas measurement in **ppm** (parts per million). Hence if the gas detector reading is 10 ppm of Hydrogen Sulphide (H₂S), the atmosphere under test contains 10 parts of H₂S and 999,990 of other gases.

How small of an amount is 1 ppm of any gas? If one (1) inch would represent one (1) ppm of gas, this would be like comparing one (1) inch in 15½-mile distance or if one (1) second would represent one (1) ppm of gas, this would be like comparing one (1) second to 11½ days.

To convert from ppm to % move decimal for places to left:

1 ppm	=	.0001%	which is	1/10,000	of	1%
10 ppm	=	.001%	which is	1/1,000	of	1%
100 ppm	=	.01%	which is	1/100	of	1%
500 ppm	=	.05%	which is	5/100	of	1%
1000 ppm	=	.01%	which is	1/10	of	1%
10000 ppm	=	1.0%	which is	10/10	of	1%

7. MATERIAL SAFETY DATA SHEET (MSDS)

After completion of this section the participants must be familiar with information given in Material Safety Data Sheet (MSDS). He/she must be able to extract the information given in regard to Product identification, Physical description and Properties.

Having a basic understanding of the different hazards is well and good, but we also need to know where we can obtain limit values.

MATERIAL SAFETY DATA SHEETS (MSDS) is one source where this information can be obtained. Most of the required information will be found under the heading **IDENTIFICATION** in the MSDS and under subheading **PHYSICAL DESCRIPTION/PROPERTIES**. The principal layout of an MSDS is outlined below.

MATERIAL SAFETY DATA SHEET (MSDS)

1. COMPANY DETAILS

Name address, phone etc. of the manufacturer, importer or supplier

2. PRODUCT IDENTIFICATION

Product name, UN number, Dangerous Goods class, Hazchem code, poison schedule, description and properties of the product

3. HEALTH HAZARD INFORMATION

Potential hazard, acute or chronic in relation to inhalation, eyes and skin. First aid information.

4. PRECAUTION FOR USE

Exposure standards, engineering controls, recommendation on personal protective equipment, flammability etc.

5. SAFE HANDLING INFORMATION

Storage and transport requirements. How to deal with spills and disposal, also fire & explosion data.

6. OTHER INFORMATION

Toxicity data.

8. GAS DETECTION

After completion of this section, the participant shall be aware of the history of gas detection. The Participant must be able to explain the principals of modern sensor technology in regard to Catalytic, Infrared and Electrochemical sensors. The principal of colour metric tubes must also be understood. The participant must also be able to explain limitations and precautions in regard to modern gas detection equipment.

8.1 HISTORY OF GAS DETECTION

The need for detecting hazards in the atmosphere is well documented. One early method was the use of a small bird placed in a cage and carried into coalmines. The theory was that the lung capacity of a bird is somewhat smaller than a human, and if gases were present the bird would be overcome first. This method was somewhat questionable in its accuracy as well as the effect on the person carrying the birdcage.



Portable gas detection instruments goes back to the late 1920's. The development of gas detectors was a direct reaction to many explosions taking place in ship's tanks. The first gas detector was a simple instrument and consisted of a squeeze bulb sample drawing model with a purely resistive, non-electronic circuit and a meter graduated in explosibility units to show the concentration of the gas detected.

During the early years of using combustible gas detectors, users also wanted a similar instrument to read the oxygen content. It was not until the 1940's such an instrument was developed. The instrument was a paramagnetic oxygen analyser utilising the magnetic properties of oxygen. In the 1960's we saw the first instrument using an electrochemical oxygen cell.

The first toxic gas indicator was developed in the late 1910's. This indicator was of a very simple nature and could only detect the presence of carbon monoxide. It would take many decades before we saw new methods to detect toxic gases.

8.2 MODERN GAS DETECTION TECHNOLOGY

Today there are many types of modern gas detectors on the market, utilising the latest technology with high accuracy. It is important to understand what method your instrument is using and the accuracy of measurements. Detectors can be in the form of portable or fixed, they can perform one function or many functions.

8.2.1 ELECTRONIC CIRCUIT

The electronic circuit has three (3) functions:

- Amplify the signal from the sensor(s)
- Provide the display showing the concentration of the gas or vapour
- Provide audible and/or visual warnings

8.2.2 SENSOR TECHNOLOGY

- The sensor is the heart of every gas detector. It responds to a gas or vapour by generating some type of electrical signal. Two (2) types are:
- Electrochemical
- Catalytic

8.2.3 OXYGEN SENSOR

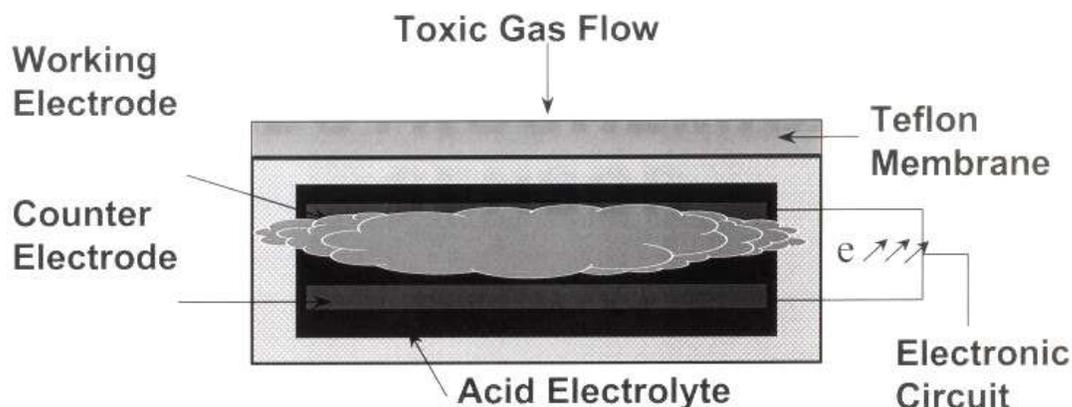
The oxygen sensor is not effected by cross sensitivity as it only sees oxygen. It is not pressure sensitive however a slight transient effect can be experienced and as such cause an alarm.

8.2.4 ELECTROCHEMICAL SENSORS

Electrochemical sensors are widely used for the detection of toxic gases in ppm and for oxygen in levels of per cent of volume (% vol).

Electrochemical sensors contain a chemical called an electrolyte which takes part in a chemical reaction with the gas under investigation producing electrons which is a tiny amount of electricity. The more gas present, the more reaction taking place so the higher the number of electrons produced.

ELECTROCHEMICAL SENSOR



Operation gas + acid electrolyte = chemical reaction /
 electrodes produce electrons proportional to amount of gas
 signal processed by electronic circuit - displays - ppm

8.2.5 TOXIC SENSORS

Electrochemical sensors are used for measurement of H₂S, SO₂ and NH₃. The Electro chemical toxic sensor specific for a particular gas can have cross sensitivity to other gases in the same testing environment. When carrying out testing in an environment where a mixture of gases are present, you must be aware that your specific gas sensor will also react to a number of other gases if present.

8.2.6 CATALYTIC SENSOR

A Catalytic sensor is the most commonly used sensor to measure combustible gases and vapours from zero to 100% LEL (lower explosions limit). Catalytic sensor technology uses a pair of computer matched elements in a circuit. The flammable gas or vapour to be measured diffuses into the sensor and on to a heated detector element and is catalytically burned. The burning gas causes the detector's temperature to increase, resulting in an increase in resistance in the element.

The reference element is coated with a non-catalytic chemical that does not react to gas and therefore has no change in resistance. The difference in resistance is used to indicate the LEL value. Most catalytic sensors are also able to compensate for changes due to temperature and humidity.

On the negative side, the catalytic sensor requires a minimum oxygen concentration of 15% by volume in the mix of diffused gas. The catalytic sensor will not indicate non-combustible gases and is susceptible to poisoning from some gases. Common poisons and inhibitors are lead, silicon, phosphorous, and sulphur.

Certain substances are able to de-sensitize the catalytic surface of the combustible detector. This can reduce the sensitivity or failure of the reading when sampling for combustible gases. The most common catalyst poisons are silicone vapours and samples containing such vapours even in small concentrations should be avoided.



The catalytic sensor requires routine calibration.

It is important to know that the sensor will react to all flammable gases. However as each gas is different the sensor will only be accurate for the gas it has been calibrated against.

See the detectors operators manual for "LEL CORRELATION FACTORS".

8.3 COLOUR METRIC TUBES



Toxic gases that are not of an organic nature can be detected by using **COLOUR METRIC TUBES**. The tubes contain a chemical reagent or substance. If the gas, which is being tested for, is present, a colour change will take place due to chemical reaction.

8.4 TESTING LIMITATIONS AND PRECAUTIONS

Several factors can interfere and give an inaccurate reading when using gas detection equipment. This interference can reduce or be eliminated by understanding the situation and take appropriate action.

8.4.1 HEATED SAMPLES

When sampling in an area that is warmer than the ambient situation (hence warmer than the instrument) condensation can occur as the sample flows through the sample line. Air will always contain water vapours. When the air passes through the cooler sample line, the air will cool off and condense and in this way block the flame arrester and interfere with pump operation. The use of a water trap or filter should be considered.

8.4.2 INTERFERENCE

There are some situations that need special consideration as certain vapours can interfere with the measurements. Water dispersant sprays and de-rusting sprays tend to affect sensors (WD40, CRC etc.)

8.4.3 ACETYLENE

Acetylene is very active catalytically and may give a reaction on the reference instrument thereby cancelling the signal from the active filament. Do not rely on combustible measurements without first making a calibration check if the instrument has been exposed to acetylene.

8.4.4 CHLORINATED VAPOURS

Chlorinated vapours e.g. Trichlorethylene, C₂HC13 and other safety solvent cleaners are not truly flammable, but can give a catalytic response thereby indicating a flammable condition where they do not actually exist. Exposure to chlorinated compounds may result in total loss of sensitivity to methane and other hydrocarbon gases. Frequent re-calibration checks must be made where it is known or suspected that these vapours are present.

8.4.5 DETERIORATION

All sensors will deteriorate with age. This means that even if an instrument is not in use, the sensor will still deteriorate. All sensors have a lifetime that is clearly indicated. Most modern instruments are capable of detecting this electronically. Always calibrate and carry out gas sensitivity response check on the day of use.

8.4.6 HOSE ABSORPTION

Most extension hoses are made of PVC or rubber and have a tendency to absorb certain vapours into or onto the hose lining. The instrument will not give an accurate reading when this happens. Toluene or Xylene is common vapours to cause such problems. Only use hoses as specified by the manufacturer.

8.4.7 TEMPERATURE RANGE

All manufacturers of gas detection equipment recommend a minimum and a maximum temperature range where the instrument will operate accurately. Avoid using the instrument outside this temperature range.

8.4.8 HUMIDITY/TEMPERATURE

Normal atmosphere will contain a certain amount of water depending on the temperature and relative humidity. Humidity and high temperatures can cause errors when testing for oxygen using a diffusion type instrument. A closed vessel is likely to have a very high relative humidity (100%) and if the ambient temperature is substantially above the ambient, the oxygen concentration will be diluted. A solution to this problem is to use a long sample drawing extension hose, which allows the sample to cool to ambient temperature. This will cause water condensation, but will allow the oxygen to be measured fairly accurately.

9. TEST PROCEDURE

Work is carried out in many areas where the atmosphere can be hazardous and must be tested accordingly. Each situation must be assessed and analysed before any work can commence.

9.1 PREPARATION

There is no room for errors when using gas detectors and the following must be established before any testing commences:

GAS DETECTOR	check battery, correct sensors, daily sensitivity response check, and calibration
CHECK WITH PERMIT PREPARER	what work is to be undertaken and establish which gas(es) are to be detected.
CHECK JSA	ensure that all identified atmospheric hazards are looked at
CHECK PERMIT	for ongoing testing (instruction for specific testing)
AMBIENT TEMPERATURE	will temperature rise during work
WIND DIRECTION	ensure wind speed and direction
SCBA	make sure self-contained breathing apparatus is available

9.2 TASK – LOCATION

It is impossible to collate a complete list of tasks and locations where the atmosphere must be tested. If at any state it is expected that the atmosphere is hazardous, work must not commence or continue until appropriate testing has been carried and the result assessed.



- The following tasks and locations are known to have possible hazardous atmosphere:

Confined Space	Pits
Piping Systems	Pipe Flanges
Bunds	Valve Glands
Drains	Hot Work
Relief Valves	Pressure Vessels

9.3 WHERE TO TEST

This is complex as we are dealing with gases, both lighter and heavier than air, that are at very much higher pressure and may be situated outdoors, in louvered modules or in areas where there is forced ventilation. Because a leak in these conditions may result in a very rapid build-up of concentrations an appreciation of gas cloud movement becomes critical. Among the many variables to be considered are:

- Direction of prevailing wind for external protection
- Nature of ventilation system, mass flow and direction
- Temperature and density of gases
- Pressure within plant and vessels and pipes
- Nature of structure housing plant and location of sumps or high level traps

Since many areas can contain both heavy and light gases, accumulation of gas will occur at both high and low levels. In general terms it is prudent to look for the lowest floor levels such as sumps and drains but also high levels such as pitched roofs as accumulation points, but additionally the direction of air flow due to ventilation must be considered.

9.3.1 INITIAL DISPERSION

In the absence of air movement or any confining structure, the dispersion of flammable gas from a source of release will initially be determined by the momentum of the gas released, it's density relative to air or both.

Gas escaping from high velocity will behave initially as a momentum jet directed away from the source of release. As the distance from the source of release increases, the buoyancy effects will control the momentum of the jet decay until eventually the dispersion of the gas.

The behaviour of gas released with negligible initial velocity will be governed by buoyancy and will depend on the relative density of the gas with respect to air. If there is significant air movement or the release is into confined spaces then the above behaviour will be modified.

It is worth noting that clouds may be significantly more dense than the surrounding atmosphere for two reasons:

- If the molecular weight is greater than that of air, particularly if the relative vapour density is greater than 1.05, then the density effects becomes noticeable.
- Temperature differences also lead to density differences. With an otherwise neutrally buoyant gas cloud, it can be shown that a temperature difference of a little more than 1°C is sufficient to bring about significant flow due to density effects.

9.3.2 OUTDOOR SITES & 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 the wind direction. In open areas, the lateral spread of gas upwind of the release will be reduced, whilst downwind 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.

9.3.3 CHEMICAL REACTION

Even though initial testing could indicate low concentrations of flammable or toxic gases, it must be kept in mind when determining the frequency of testing, that the situation can change rapidly. A liquid can be incompatible with oxidising agents, acids, active metals and heat sources and generate an explosive atmosphere.

Furthermore, the introduction of water can cause an increase in toxic gases as well as rises in temperature. Removal of scales and linings can free pockets of gas concentrations.

9.4 WHEN & HOW OFTEN DO WE TEST?

The question of when and how often one should test will depend on several factors and past experience will assist. Factors that will influence frequency of testing can be:

- ◆ Layout of area and equipment
- ◆ the process
- ◆ Work to be carried out
- ◆ Environmental (wind and temperature)

9.4.1 INITIAL TESTING

Where oxygen deficiency, flammable & toxic gases are suspected always test:

- When carrying out risk assessment
- When preparing the permit
- Where hot work is required in Hazardous areas
- Before entry into confined space

9.4.2 INTERMITTENT (REPEAT) TESTING

When assessment and conditions indicates the possible risk of gases or oxygen deficiency, intermittent testing should be carried out at least every hour.

9.4.3 CONTINUOUS TESTING

Continuous testing is recommended in the following situations:

- ◆ During hot work in Hazardous Zone
- ◆ During hot work in Confined Space
- ◆ When LEL is above 0 in Confined Space
- ◆ When SCBA is used in Confined Space
- ◆ When solvents are used in Confined Space
- ◆ When permit requires

9.5 HOT WORK

Whenever 'hot work' is to be carried out, particular attention must be taken in regard to a possible explosive atmosphere. Furthermore a clear understanding of hazardous zones is a must.

'Hot work' includes work such as:

- **operating portable electrical power tools**
- **arc welding**
- **gas cutting**
- **gas welding**
- **using angle grinders**
- **abrasive blasting**
- **use of non-intrinsically safe electrical equipment**
- **placing a generator in a hazardous area (explosive atmosphere)**

It is of the upmost importance that the **Authorised Gas Tester(A.G.T.)** has obtained detailed information in regard to what type of hot work is to be carried out from the permit preparer. Specific details must be paid to the method of hot work i.e. will welding or cutting be carried out using oxygen, acetylene or another inert gas, will cleaning solvents be introduced, has a tank contained hydrocarbons.

If pipe work is to be welded such pipe work should have an avenue or opening so that the inside of the pipe can be tested. Likewise the area that requires to be tested must be clearly defined. It is prudent to test an area where pits, drains, flanges and relief valves are located within a 15 metre radius of the intended hot work.

Attention must be paid to current climate conditions but also to changes that can occur i.e. wind direction and speed, increase in temperature e.t.c. It is advisable to carry out continuous testing for all hot work.

9.5.1 HIGH RISK HOT WORK

High risk hot work in an IGNITION RISK AREA requires:

- Initial gas sampling to confirm that explosive gas concentrations are below LEL
- Continuous gas monitoring throughout the life of the work

9.5.2 LOW RISK HOT WORK

Low risk hot work in an IGNITION RISK AREA requires:

- Initial gas sampling to confirm that explosive gas concentrations are below LEL
- Two hourly gas monitoring throughout the life of the work

9.5.3 HOT WORK SPECIFIC

Any portable gas detection equipment that is going to be used in hazardous areas must conform to **AS2275.1 and be certified intrinsically safe**. It is also critical that no batteries are changed or replaced in a hazardous zone.

In order to analyse where testing is required and how testing should be carried out you must keep in mind the possible ignition sources:

- **Naked flames**
- **Electrical sparks from power sources**
- **Hot surfaces e.g. exhaust manifolds, light fittings**
- **Frictional sparks e.g. alternators**
- **Pyrophoric materials (spontaneously flammable)**
- **Radiation**
- **Static electricity**

9.5.4 THE NATURE OF THE ENVIRONMENT

- ◆ Check with the permit preparer exactly what work is to be undertaken and define the area to monitor i.e. all pits, drains, flanges, relief valves etc. within a 15 metre radius of intended hot work.
- ◆ What type of area you are dealing with, is it enclosed or is it an open area? This is most important because a flammable gas will generally disperse very rapidly where there is substantial airflow.
- ◆ Identify what type of gases you are dealing with.
- ◆ What are the climate conditions and what will they be like during work. Establish approximate wind speed and direction
- ◆ Where is hot work equipment going to be located i.e. site of generator or compressor?
- ◆ Does the job require continuous testing?
- ◆ If hot work, performed in a high risk area, continuous testing must be carried out.
- ◆ Does hot work include operation of vehicles or combustion engines?
- ◆ Look at an area within a 15 metre radius of routes those vehicle travel. Walk the exact route of the hazardous area that vehicles will travel.
- ◆ If pipe work is to be welded such pipe must have an opening so that the inside of the pipe can be tested.



10. CONFINED SPACE

Death and injury in confined spaces can result from many different causes, including asphyxiation, inhalation of toxic gases and vapours or explosion. Most accidents within a confined space are related to the atmospheric conditions. It is a well-known fact that the risk for a serious or fatal accident is many times higher when working in confined space compared with a normal working situation.

It is a must to carry out testing of LEL, Oxygen and toxic gases before issuing a permit to enter a confined space. Continuous testing can also be required during work in confined space.

10.1 AUSTRALIAN STANDARD (AS2865 2009)

Australian Standard, AS 2865 sets out procedures for safe working in confined space. This standard requires us to test for:

- (a) **OXYGEN CONTENT**
- (b) **FLAMMABLE CONTENT**
- (c) **POTENTIAL TOXIC GASES**

Testing should be carried out and assessed:

- (a) **BEFORE ENTRY PERMIT IS ISSUED**
- (b) **IF CHANGE IN WORKING ATMOSPHERE & ENVIRONMENT**
- (c) **IF LEL IS GREATER THAN 5% AND LESS THAN 10% OF LEL (CONTINUOUS MONITORING).**

Testing should be carried out from:

- (a) **FROM OUTSIDE CONFINED SPACE (remote testing)**
- (b) **INSIDE CONFINED SPACE for remote regions that can not be reached by remote sampling (use of SCBA could be required)**
- (c) **INSIDE CONFINED SPACE (continuous monitoring)**

AS 2865 specifies parameter for Safety of the atmosphere and they are:

SAFE OXYGEN	19.5% - 23.5%
FLAMMABLE	Below 5% of its LEL
TOXIC CONTAMINANTS	Below relevant exposure standard

AS 2865 requires that testing is carried out by a competent person and has defined a competent person to be:

A PERSON WHO HAS, THROUGH A COMBINATION OF TRAINING, EDUCATION AND EXPERIENCE, ACQUIRED KNOWLEDGE AND SKILLS ENABLING THAT PERSON TO PERFORM A SPECIFIED TASK.

10.2 CONFINED SPACE TEST PROCEDURE

The **PERMIT PREPARER** specifies gas-testing requirements. However a thorough understanding of the **JSA** and its content will greatly assist the **GAS TESTER**.

10.3 LEL

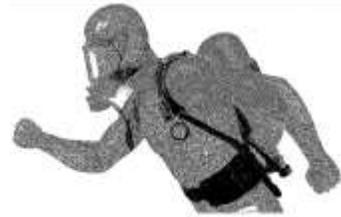
When testing a confined space before entry, a sample should be drawn from outside the confined space using extension hose/cable (remote testing).

Entry to confined space, even for testing, with or without the use of SCBA, cannot be permitted until the atmospheric characteristics have been established.

Sampling should take place at the levels where flammable gases can be expected. Always remember what is the gas you are looking for, lighter than air, heavier than air or similar to air.

10.4 OXYGEN & TOXIC GASES

If no flammable atmosphere is noticed, testing can now be carried out for Oxygen and other toxic gases. We must test at different levels and different locations particularly if the confined space includes sections, walls pipes and other obstruction that can lead to isolation of an area within the confined space.



If entry is required to establish levels of Oxygen and toxic gases, SCBA must be worn and a stand-by person with SCBA must be present and permission given to enter by Permit preparer or other authorised competent person.

10.4.1 ESTABLISH OXYGEN LEVEL

The JSA will indicate what work process is going to take place. If this process can result in deterioration of oxygen levels, continuous testing must be carried out.

After establishing the level of toxic gases consider the work process. Is there a possibility of chemical reaction, is water introduced to an acid atmosphere etc.? These situations would warrant continuous testing.

- ◆ Check with permit preparer exactly what work is to be undertaken and define area to monitor i.e. all pits, drains, flanges, relief valves etc. within a 15 metre radius of intended hot work.
- ◆ Identify what type of gases you are dealing with.
- ◆ Will chemicals (solvents etc.) be used? Can residue of content react with water or other substances that are introduced?
- ◆ What are the climate conditions and what will they be like during work. Establish approximate wind speed and direction
- ◆ Where is hot work equipment going to be located? i.e. site of generator or compressor.
- ◆ Does the job require continuous testing?
- ◆ Is hot work of high risk? If so, continuous testing must be carried out.
- ◆ Does work include operation of vehicles or combustion engines?

10.5 TESTING REQUIREMENTS

- Sampling must be carried out no more than 2 hours prior to initial entry into confined space
- Powered ventilation devices must be turned off at least half an hour before the initial gas test is carried out
- Repeat testing must never exceed four hours after initial test
- Continuous monitoring is required for restricted entry and must include; oxygen levels, flammable and toxic gases

10.5.1 ATMOSPHERIC REQUIREMENTS FREE ENTRY

- **CO** must be less than 15 ppm for free entry
- **H₂S** must be less than 5 ppm for free entry
- **SO₂** must be less than 1 ppm for free entry
- **NH₃** must be less than 10 ppm for free entry
- **O₂** must be greater than 19.5% and less than 23.5% for free entry
- **Other gases and vapours** must be less than 50% of the TLV for free entry
- **LEL** must be less than 5%

10.5.2 ATMOSPHERIC REQUIREMENTS RESTRICTED ENTRY

- Restricted entry into confined space can only be authorised in accordance with site policy

11. RECORDING

It is critical that all test results are recorded in detail. The proper forms must be used at all times.

11.1 CONFINED SPACE

- The initial test results must be recorded on the **CONFINED SPACE ENTRY CERTIFICATE**
- Periodical testing as stated for gas testing frequency shall be recorded on 9 **ATMOSPHERE LOG SHEET**.
- **CONTINUOUS TESTING** also needs to be documented on 9 Atmosphere Log Sheet

11.2 HOT WORK

- **Hot Works Permit must be used where required**