

Introduction to the Detection and Control of Hazardous Materials





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of:

Saga Universal Training Corporation

Saga Universal Training Corp. is dedicated to reducing deaths caused by illness and injury. This manual follows the guidelines, principles and recommendations established by common Occupational Health and Safety legislation and industry established and accepted safety standards.

This training course is intended to supplement employer training programs. Readers should not assume that reviewing this manual alone constitutes complete Gas Detection and Control training.

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Saga Universal Training Corp. wishes to acknowledge the efforts of all the people who contributed to the writing, editing, and layout of this manual. It is our hope that this manual and the resulting training program will aid in the reduction of preventable injuries with the necessary knowledge, skills and confidence to understand hazards associated with Hazardous Materials.





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Section 1

Hazardous Materials





This section discusses what hazardous materials are and the types, characteristics and likely locations of these materials.

Learning Objectives:

1. Become familiar with the term hazardous materials
2. Identify the types of hazardous materials
3. Identify the states of matter
4. Become familiar with the characteristics of materials
5. Understand the three elements of the fire triangle
6. Understand the four elements of the fire tetrahedron
7. Become familiar with the concept of flammable limits
8. Become familiar with Safety Data Sheets (SDS)
9. Identify some of the likely locations of hazardous materials

Introduction to Hazardous Materials

As part of an employer's responsibility, an employer must ensure that workers are protected from the effects of Hazardous Materials. Hazardous materials can be defined as any material that, because of its quantity, concentration, or physical or chemical characteristics, may pose a real hazard to human health or the environment.

Hazardous Materials may include:

- ☑ **Flammable and Combustible materials.** These are materials, that while in their vapour state and blended with oxygen in the right proportions and exposed to a sufficient source of ignition will combust.
- ☑ **Explosives.** These are materials that are either chemically or otherwise energetically unstable or produces a sudden expansion of the material usually accompanied by the production of heat and large changes in pressure (and typically also a flash and/or loud noise).
- ☑ **Toxic or Poisonous Materials.** These are materials that when exposed to humans may cause serious adverse health effects.
- ☑ **Corrosive Materials.** These are materials that may cause irreparable skin and/ or eye damage upon contact.
- ☑ **Radioactive Materials** are those materials that when exposed to humans will cause a deterioration or breakdown of cell tissues and organs. Naturally occurring radioactive materials (*NORM*) may be found in the production of oil & gas sector.
- ☑ **Oxidizers** are materials that may provide additional oxygen to a fire either naturally or while combusting. This enhanced oxygen will cause combustion to occur at a much faster rate than normally would occur.

- ☑ **Aerosols** are a dispersion of solid and liquid particles suspended in gas. These materials may present a health, fire or explosion hazard.
- ☑ **Compressed Gases** are gases found stored under high pressure. In addition to the high-pressure hazard, the gases may be flammable; corrosive; toxic; oxidizing; inert; or, dangerously reactive.
- ☑ **Biohazardous materials** are infectious agents or hazardous biological materials that present a risk or potential risk to the health of humans, animals or the environment.

The most effective way to ensure that workers are protected from the exposure to Hazardous Materials is to perform a comprehensive **Hazard Assessment**.

States of Matter

As Sir Isaac Newton discovered, a material can neither be created nor destroyed. However, the natural state of the material can be changed in one of two methods; by changing the temperature and/or the pressure upon the material. This is important to understand because both factors could change the behaviour of the material from its normal behaviour. Normal behaviour of materials is based on “normal” atmospheric conditions. Normal atmospheric conditions are based on a specific atmospheric temperature and atmospheric pressure measured at sea level. For the purposes of our understanding we will use 20°C and 101.5 kPa as our baseline atmospheric conditions. These two conditions dictate what state of matter the material will reside in, and therefore, what their characteristics are and how they will behave.

There are generally 3 states of matter: **Solids, liquids, and vapours or gases**. However, the normal state of the matter can be changed through changing atmospheric conditions.

Increasing the temperature upon materials will cause solids to liquefy and further temperature increases will cause liquids to vapourize. Realize however, that some materials will change from a solid straight to a vapour without liquefying. And, of course, if the temperature were to decrease upon a material the process of change would be reversed; vapours to liquids to solid form.

Also having an affect on the physical states of matter is pressure; however, the effects are opposite to the effects of temperature. Increasing the pressure upon a vapour will cause it to liquefy and further increasing the pressure causes those liquids to solidify. And again, if the pressure were to be decreased upon the materials, the process would be reversed.

And finally, a combination of changing temperatures and pressures upon materials will have an effect on those materials. The changes to materials based

on changing conditions are specific to the actual material, or combination or blend of materials.

The following chart is intended to outline the effects of changing temperatures and pressures upon materials.

Temperature increase	Solid → Liquid → Vapour
Temperature decrease	Vapour → Liquid → Solid
Pressure increase	Vapour → Liquid → Solid
Pressure decrease	Solid → Liquid → Vapour

Oil & Gas – how it's created.

Most hazardous materials are created through the decomposition or biodegrading of natural, carbon based organic materials. Essentially the reducing of the flora and fauna; or, plant and animal matter create what we know as oil and gas.

As a result of the exothermic reaction created through the process of decomposition, temperature and pressure increases upon these natural materials creating solids, liquids and gases. The matter is not destroyed; it is simply changed to coal, oil and gas.

Oilfield solids are carbon-based substances. They include asphaltenes (tar), iron sulphide, coal charcoal, paraffin and greases. Liquids include crude oils, refined diesels and gasoline, petroleum solvents and distillates. Vapours include methane, ethane, propane, butane, heptane, hexane, and a few others, as well as contaminant gases such as hydrogen sulphide.

Characteristics of Materials

Based on what we have determined to be normal atmospheric conditions, materials present with characteristics specific to the material and can be measured. However, if atmospheric conditions change, the characteristics of the materials may also change. If a material has characteristics that may cause harm to people or the environment because of its quantity, concentration, or physical or chemical characteristics, they are listed as hazardous materials.

Characteristics of materials include:

- ☑ Thermal properties
- ☑ Chemical properties
- ☑ Physical properties
- ☑ Biological properties

Specific characteristics of hazardous materials are outlined in the materials Safety Data Sheets (SDS's) specific to those hazardous materials.

The three main atmospheric hazards involved in the oil and gas industry are:

- Oxygen deficiency/enrichment,
- Combustible gases and,
- Toxic gases.

Vapour Density

Vapour density is the weight of a gas (vapour) compared to air. Air (or hydrogen in some cases) is used as the medium and has a vapour density equal to one (1). If the gas has a vapour density **greater than** one (1) it will sink in air. Propane for example, has a vapour density of 1.5; therefore, propane will normally sink to the ground and seek low-lying areas. Hence the reason why propane powered vehicles are not allowed in underground parking garages. If the vapour density is **less than** one (1) the vapour will rise in air. An example is methane with a vapour density of 0.6.

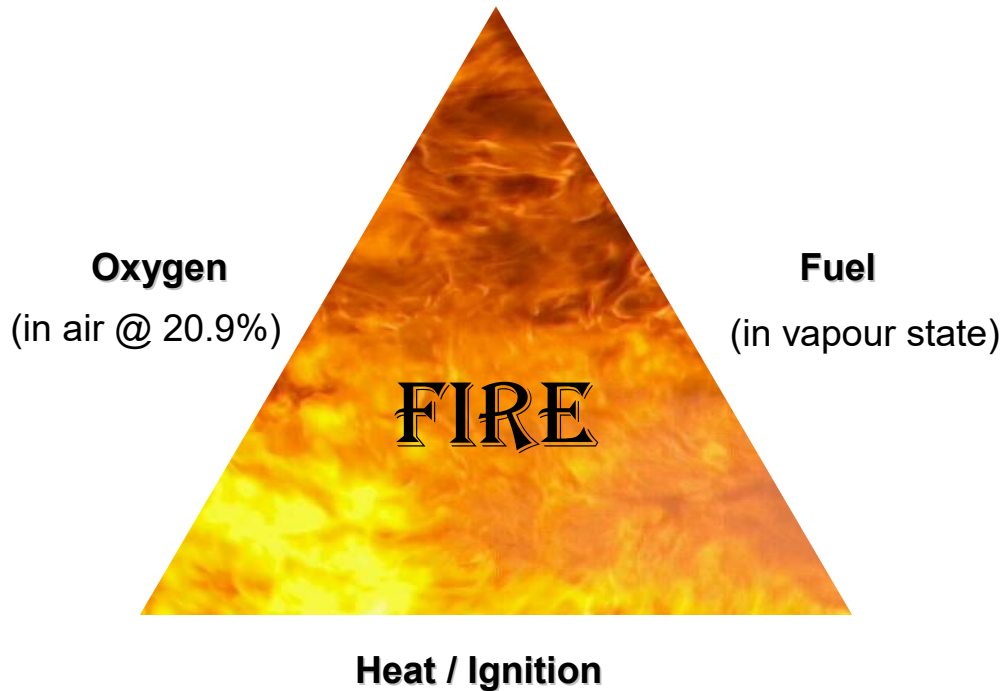
Methane = 0.6
Air = 1
Propane = 1.5

The following chart outlines common characteristics of materials...

Product	Flash-point	Flammable Range	Physical Description	Main Danger	Max Level Permitted in Air	IDLH	Specific Gravity (Water = 1)	Vapour Density (Air = 1)
Carbon Dioxide (CO ₂)	N/A	N/A	Colourless Odourless	Displaces Oxygen	5000 ppm	50,000 ppm	1.52	1.5
Carbon Monoxide (CO)	N/A	12.5% - 74%	Colourless Odourless	Toxic – Asphyxiant	25 – 200 ppm	1,500 ppm	N/A	0.97
Diesel Fuel	≥ 40°C	0.7% - 6%	Clear to Yellow / Brown	Toxic – system depressant	N/A	N/A	N/A	4.5
Unleaded Gasoline	-30°C	1% - 7.6%	Colourless Sweet Odour	Toxic – system depressant	500 - 1500mg/m ² 300 – 500 ppm	Avoid explosive Levels	.74	3.5
Hydrogen Sulfide (H ₂ S)	N/A	4% - 44%	Colourless	Very Toxic – can cause Respiratory Failure	10 – 20 ppm	100 ppm	N/A	1.2
Methane (CH ₄)	-188°C	5% - 15%	Colourless Odourless	Fire and Explosion	20% of LFL	Avoid explosive Levels	.47	0.6
Nitrogen (N ₂)	N/A	N/A	Colourless Odourless	Displaces Oxygen	Ensure oxygen is at least 19.5%	Displaces Oxygen	N/A	.97
Nitrogen Dioxide (NO ₂)	N/A	N/A	Reddish / Brown Pungent odour	Toxic – severe Respiratory Irritant Disturbance	3 – 5 ppm	50 ppm	N/A	1.6
Propane (C ₃ H ₈)	-104°C (boiling pt. -42°C)	2.1% - 9.5%	Naturally odourless, stenching added	Fire and Explosion	2500 ppm	Avoid explosive Levels	N/A	1.5
Sulfur Dioxide (SO ₂)	N/A	N/A	Colourless Suffocating odour	Toxic – severe Respiratory Irritant	2 – 5 ppm	100 ppm	N/A	2.2

Fire Triangle

Fire is a rapid, self-sustaining chemical reaction that presents itself in the form of heat and light. There are three separate elements that have to come together for a fire to occur. The fire triangle outlines the elements of a fire that react. These elements include Oxygen, Fuel, and Heat.



Oxygen – The air with breath contains about 20.9% oxygen. Fires burn “normally” at this concentration. However, fire only needs 16% oxygen to ignite. Oxygen concentrations above 20.9% allow the burning process to be enhanced. Materials may explode if oxygen concentrations are above 23%.

Certain materials such as oxidizers may further enhance the burning process or burn in an otherwise oxygen deficient atmosphere. Examples include:

- ✓ Magnesium
- ✓ Titanium
- ✓ Zirconium
- ✓ Potassium
- ✓ Lithium
- ✓ Calcium
- ✓ Zinc
- ✓ Sodium

Fuel – Essentially, all materials on earth will burn. However, for materials to burn they must first be vapourized. It's important to mention the three states of matter; solids, liquids, & gases and how they change. Temperature and pressure cause states of matter to change; but different materials require different temperatures and/or pressures in order to change.

Primarily, states of matter change with temperature. For example, if an ice cube is heated to 0°C at sea level, the solid changes to a liquid. If the water is further heated to 100°C it will change again to a vapour.

The other way states of matter change are through pressure. For example, propane will normally be found in its vapour state. However, if propane is pressurized and contained in a vessel, it changes to a liquid state, without changing the temperature. This explains why propane is found liquefied inside an ordinary propane cylinder yet burns as a vapour.

Heat – Heat is defined as a type of energy transferred between two bodies of differing temperatures. Heat is first needed to raise the temperature of a material to the point at which it starts to vapourize (flashpoint) and then to raise the temperature further to the point at which the vapours will ignite (ignition temperature).

Heat can be transferred through conduction, convection and radiation.

Heat changes products in one of the following ways:

Solid state + Pyrolysis = Fuel Vapour

Liquid state + Vapourization = Fuel Vapour

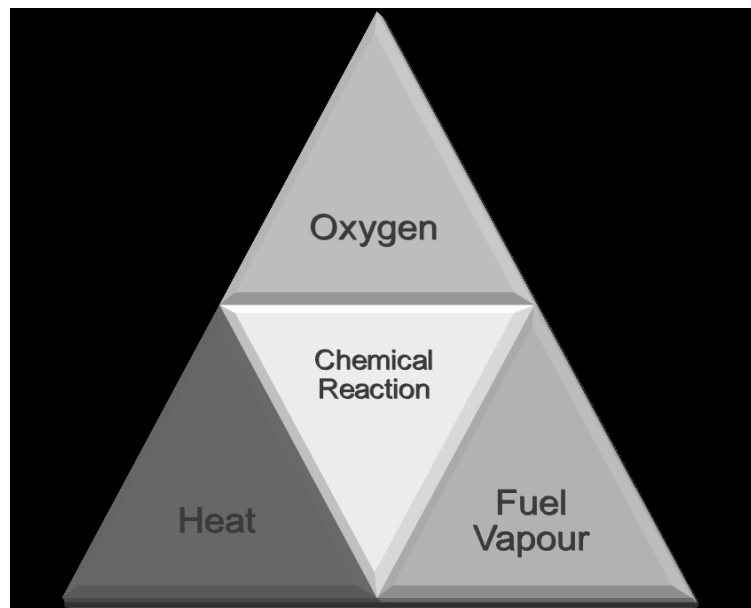
Vapour state = Fuel Vapour

Some of the more common heat sources include:

- Direct Flame contact
- Electricity
 - Direct Current
 - Static
- Friction
- Sparks from hot work
- Radiation from the sun or a heater
- Conduction through metal

Fire Tetrahedron

The fire tetrahedron theory represents a four-sided object that looks like a pyramid. It includes the components of the fire triangle with one additional component, a “chemical chain reaction”. The elements of the fire tetrahedron are described as the following:



Oxidizing Agent (Oxygen) – This includes oxygen in air and oxidizing agents. Oxidizing agents produce oxygen through the chemical chain reaction of the substance burning.

Reducing Agent (Fuel) – Whenever a substance burns it changes its molecular composition. This is what we call the “reducing agent”, often solid substances turn into an ash when they are burned.

Temperature (Heat) – In order for something to catch fire, it needs to be exposed to some form of ignition source or heated up to its ignition temperature.

Chemical Chain Reaction – This occurs when oxygen, fuel, and heat come together in the right amounts and under the right conditions. Again, this chemical reaction presents itself in the form of heat and light and is known as a fire.

Eliminate any one element of the fire tetrahedron, and a fire cannot exist.

Combustion range

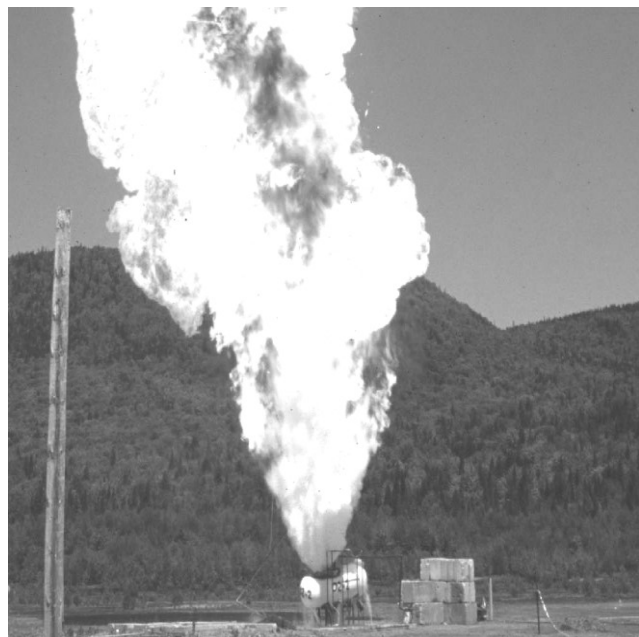
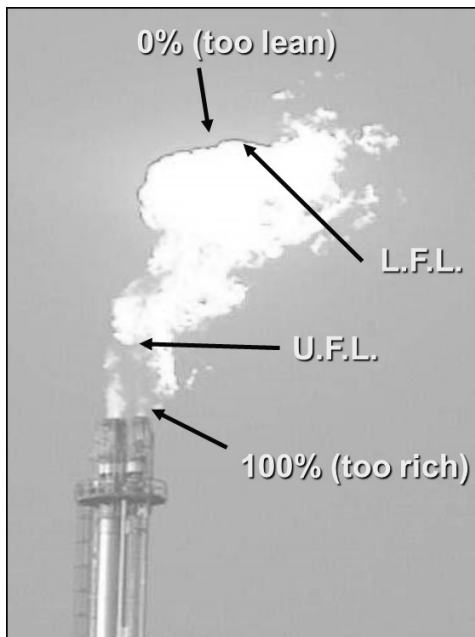
As outlined in the process of combustion, oxygen, fuel and heat must come together for either a fire or an explosion to occur. Further realize however, that each or the elements must be in the correct quantities. For example, you might think that an equal blend of oxygen and fuel vapour would be ripe for combustion. However, as outlined in the chart of common hazardous materials, the blend of fuel vapour in air necessary for combustion is specific to each fuel. As is the amount of heat necessary to ignite the vapour, air mixture.

Lower Flammable Limit (LFL) – is the **lowest** concentration of flammable vapour **in air** that will support combustion. This is also referred to as the “Lower Explosive Limit”.

Upper Flammable Limit (UFL) – is the **highest** concentration of flammable vapour **in air** that will support combustion. This is also referred to as the “Upper Explosive Limit”.

If the concentration of fuel vapour in air is less than a fuels lower flammable or explosive limit, the mixture will not combust. It is stated that the fuel/air mixture is too lean to combust. Vapours below their combustion range may escape to atmosphere as fugitive emissions.

Conversely, if the concentration of fuel vapour in air is more than a gas’s upper flammable or explosive limit, the mixture will also not combust. Here it is stated that the mixture is too rich to combust. Typically, these fuels will be diluted to within their combustion ranges and given a sufficient heat source to ignite.



Safety Data Sheets (SDS's)

A Safety Data Sheet (SDS) is a document that contains information on the potential hazards (health, fire, reactivity and environmental) and how to work safely with the chemical product. It is an essential starting point for the development of a complete health and safety program. It also contains information on the use, storage, handling and emergency procedures all related to the hazards of the material.

The SDS contains much more information about the material than the label. SDS's are prepared by the supplier or manufacturer of the material. It is intended to tell what the hazards of the product are, how to use the product safely, what to expect if the recommendations are not followed, what to do if accidents occur, how to recognize symptoms of overexposure, and what to do if such incidents occur.

There are sixteen (16) categories of information that must be present on an SDS in Canada. These categories are specified in the Controlled Products Regulations and include:

- | | |
|--|-------------------------------------|
| 1. Product Identification: product name, manufacturer and suppliers' names, addresses, and emergency phone numbers | 8. Exposure Controls / PPE |
| 2. Hazardous Identification | 9. Physical and chemical properties |
| 3. Composition / Information on ingredients | 10. Stability and reactivity |
| 4. First-aid measures | 11. Toxicological information |
| 5. Fire-fighting measures | 12. Ecological information |
| 6. Accidental release measures | 13. Disposal considerations |
| 7. Handling and storage | 14. Transport information |
| | 15. Regulatory information |
| | 16. Other information |

The Controlled Products Regulations prescribes what information must be present in more detail.

Section 2

Detection of Hazardous Vapours



This section discusses atmospheric hazards; atmospheric sampling devices and issues and limitations; care and preparation of gas monitors; hazard assessment and the operational range of gas monitors.

Learning Objectives:

1. Become familiar with the three main atmospheric hazards
2. Understand the differences between detecting and monitoring devices
3. Become familiar with the 3 types of sensors
4. Understand the differences between personal, portable and fixed monitoring devices
5. Become familiar with the components of an area-wide controller/sensor system
6. Be familiar with, and understand electronic monitoring device issues
7. Be familiar with the bump test and the full calibration methods
8. Understand when to use the bump test method or the full calibration method
9. Be familiar with how to perform a bump test
10. Understand the term calibration drift
11. Be familiar with the causes of calibration drift
12. Understand the difference qualitative and quantitative assessments
13. Understand the difference intermittent and continuous sampling
14. Be familiar with the gas sampling strategies: Matrix/Grid versus Spoke and Wheel
15. Understand what is meant by the acronyms: OEL, TLV, PC, TWA, STEL and IDLH
16. Be familiar with the effects of varying oxygen concentration levels
17. Be familiar with, and understand how correction factors are applied



Introduction

Legislation states: *If potential atmospheric hazard has been identified, a competent worker must perform an atmospheric test of the confined space to:*

- *Verify oxygen content is between 19.5 – 23%*
- *Identify amount of toxic, flammable or explosive substances that may be present.*

Ensure testing equipment is calibrated and used in accordance with the manufactures specifications; and, the results of the tests must be recorded.

The three main atmospheric hazards associated with confined spaces are:

Oxygen concentration

- Oxygen Deficiency
- Oxygen enrichment

Combustibles, Flammables, Explosives

- Methane
- Propane
- Gasoline
- Various other site-specific hydrocarbons

Toxins / Poisons

- Hydrogen Sulfide
- Carbon Monoxide
- Various other site-specific toxics

Measuring vapour in air

Two scales are used to measure the presence of a hazardous vapour in the atmosphere; **percentage** scale and **parts-per-million** scale.

A percentage scale is used to measure the atmosphere for potential flammable or explosive atmospheres and oxygen concentrations.

The PPM scale is used to measure potentially poisonous or toxic atmospheres.

Detector devices are typically used prior to entering a hazardous area, while monitors are used to continually “monitor” the atmosphere once entry has been made.

Parts Per Million (ppm)	Percentage (%)
1,000,000	100
100,000	10
10,000	1
1,000	0.1
100	0.01
10	0.001
1	0.0001
0.1	0.00001
0.01	0.000001

Atmospheric Sampling devices

A variety of gas sampling devices are used today. These devices include:

- Detecting Devices
 - Glass Tube Detector Devices
 - Electronic Gas Detector
- Monitoring Devices
 - Personal monitors
 - Portable monitors
 - Fixed monitors

Detecting Devices

Detector devices are typically used to detect targeted gases and vapours prior to entering a hazardous area, while gas monitors are used to continually “monitor” the atmosphere once entry has been made. The type of device used is dependent upon the workplace location, types of gas or gases likely to be found, atmospheric conditions, whether the operation is manned or un-manned etc.

Glass Tube Detector Devices

The multi-gas detector is a set of portable gas detector, which consists of two main components - a manually operated pump and detector tubes. The types of detector tubes available in the Service include Polytest; Carbon Monoxide; Chlorine; Hydrocyanic Acid; Hydrogen Sulphide; Oxygen; Trichloroethylene; Thioether; Organic Basic Nitrogen Compounds; Organic Arsenic Compounds and Arsine; Phosgene; Cyanogen Chloride and Phosphoric Acid Esters.



Function

The multi-gas detector is used to detect targeted gases and vapours in sewers and confined spaces. The detector tubes are glass vials filled with a chemical reagent that reacts to a specific chemical or family of chemicals. A calibrated concentration of air sample is drawn through the detection tube with the bellows pump. If the targeted chemical(s) is present the reagent in the tube changes colour and the length of the colour change indicates the measured concentration.

Detector Tubes and when to use them

A detector tube is a graduated glass tube filled with chemical reagent that will produce a colour change, when exposed to the gas in question. It is used with a hand pump that will draw a sample into the tube.

The tubes are generally supplied in packages of ten and are sealed at both ends. In operation, the tips are broken off, and the tube is inserted into the hand pump. Depending on the manufacturer, the pump utilizes either a bellows or piston design, drawing a 100-milliliter sample through the tube.

As the sample works its way up the tube toward the pump, it reacts with the reagent such that the length of the colour change produced is proportional to concentration. The point where this reaction stops is read off against graduated markings on the tube.

Detector tubes are easy to use, are relatively inexpensive, and the method is intrinsically safe, allowing it to be deployed in all occupancies.

Since detector tubes are available for hundreds of compounds and have been around in a practical format since the 1930s, they are familiar to virtually anyone working in gas detection. But, seventy or so years after their introduction, there are now scores of gas detection instruments available. Thus, one might well ask when it is appropriate to use detector tubes.

We should first consider some of the disadvantages of detector tubes:

- Tubes are not very **accurate**. At best, expect $\pm 20\%$ of actual reading.
- Tubes can be quite temperature sensitive, and although correction data is customarily provided by the manufacturer, in practice it is not frequently applied. This is usually because the tube data sheet, supplied in the package, is not brought into the field by the user. Out of sight, out of mind.
- Owing to their basis in colourimetric reactions, the tubes have a shelf life, and many of them have to be stored at cold temperatures.
- While detector tubes are available for hundreds of compounds, there are

far fewer unique reaction chemistries. As such, tubes are prone to interferences from other gases. To their credit, the manufacturers document these interferences.

- Even if you are told that compound "x" may interfere with the measurement of your target compound, you may have no idea if compound "x" is present, or at what concentration it may be present. Furthermore, a specific interference ratio is seldom given, and since the method is based on colourimetric reactions, certain compounds can bleach out the colour change that should otherwise occur.
- Many tubes require that multiple pump strokes (creating multiples of the basic 100 ml. sample size) be taken, to achieve the desired sensitivity. Errors can occur either from the failure to keep track of the number of strokes, from not allowing sufficient time for each sample to work its way through the tube before taking another pump stroke, or from "pre-cleanse" layers of the tube (intended to remove water vapor or other chemicals) being used up as they are taxed beyond their capacity.

Although so-called long-term detector tubes are available for a small number of compounds, the far more common standard tubes can only give the user a grab-sample "snapshot" of the air and can never substitute for real-time monitoring.

For the most part, detector tubes are best used when a quick and dirty test will suffice. Examples would include:

- Testing around plumbing components where a leak is suspected, and it is known what compound would be leaking.
- cursory evaluation of hazardous material spill situations, especially when more appropriate instruments are not available.
- cursory evaluation of nuisance odour complaints, especially if there is a suspect compound.

Back in the day, the biggest advantage of tubes was that they were cheap. However, at upwards of \$100.00 per package (March 2017), and considering that inexpensive instruments are now available for many of the most common toxic compounds, this advantage is rapidly disappearing.

As suggested by the "quick and dirty" examples above, tubes have a place for one-shot evaluations, but are simply not appropriate for routine or prolonged use in the same location. After all, once a toxic gas problem has been identified, it must either be eliminated or continuously monitored.

A simple rule of thumb would be to question any routine or repeated use of detector tubes. There will almost always be a better way to fulfill the gas detection application.

Operating Procedure

1. Check Aspirating pump.

Check the pump for leaks in accordance with the manufacturer's specifications.

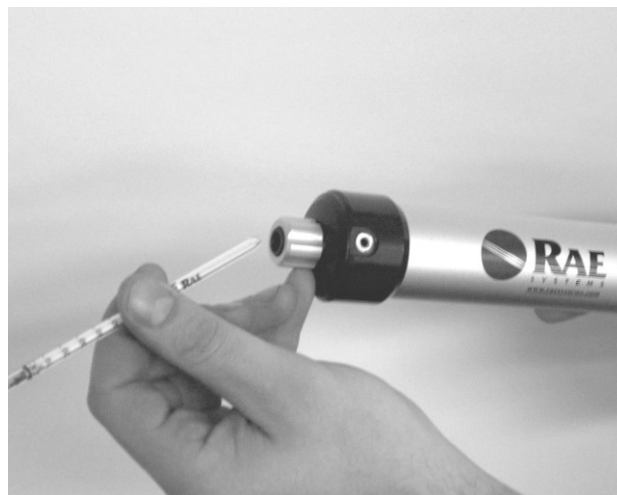
2. Break both ends of the gas detector tube.

Insert the tip of the gas detector tube into the tip breaker and pull towards you. The broken tip will fall into the tip reservoir and can be disposed of later.



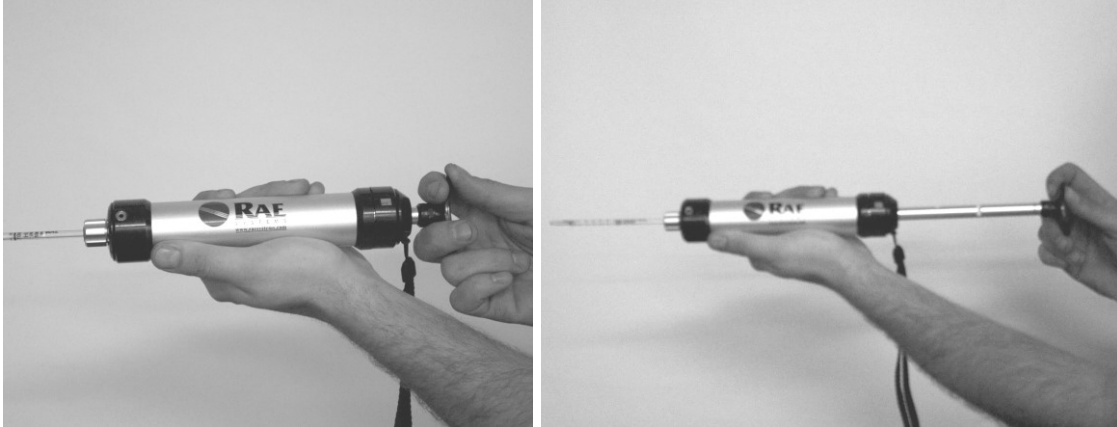
3. Connect the gas detector tube to the aspirating pump.

The sample gas must be drawn through a gas detector tube in the correct direction. Insert the gas detector tube into the rubber tube connector with the tube's directional arrow pointing towards the pump.



4. Pull the handle.

Align the red line on the bottom case and that on the shaft and pull the pump handle to its full 100ml locking position. If the sample calls for a half stroke, pull out pump handle until 50ml line appears, and shaft will be locked at 50ml.



5. Draw the sample gas.

Draw the sample gas for the specified time at the desired sampling point and confirm with the flow indicator that the sample is completed. The sample time required for each detector tube is stated clearly in the instruction sheet.



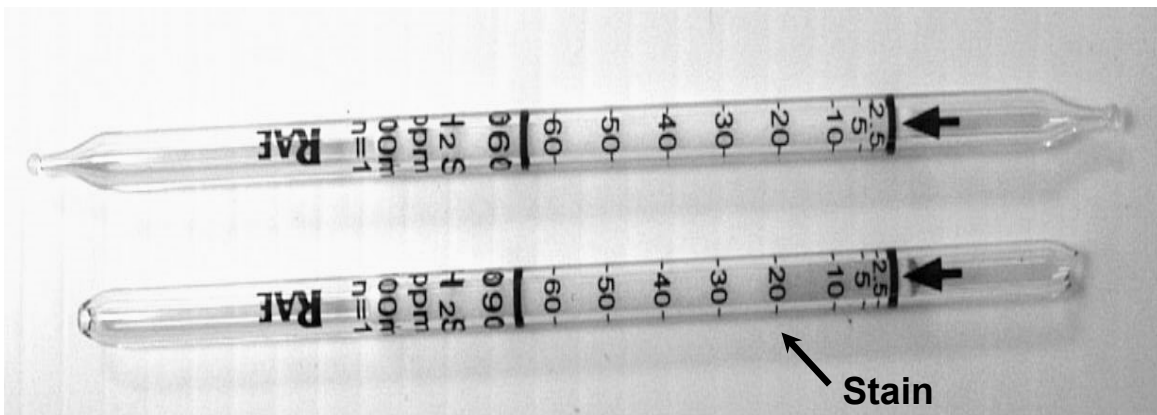
6. Return the handle.

When the sample is completed, turn the handle 1/4 turn (90 degrees) clockwise or counter clockwise to unlock the handle. Some detector tubes require extra pump strokes (i.e. more than 100ml of air). In this case, push back the handle and repeat the operation.



7. Read the concentration.

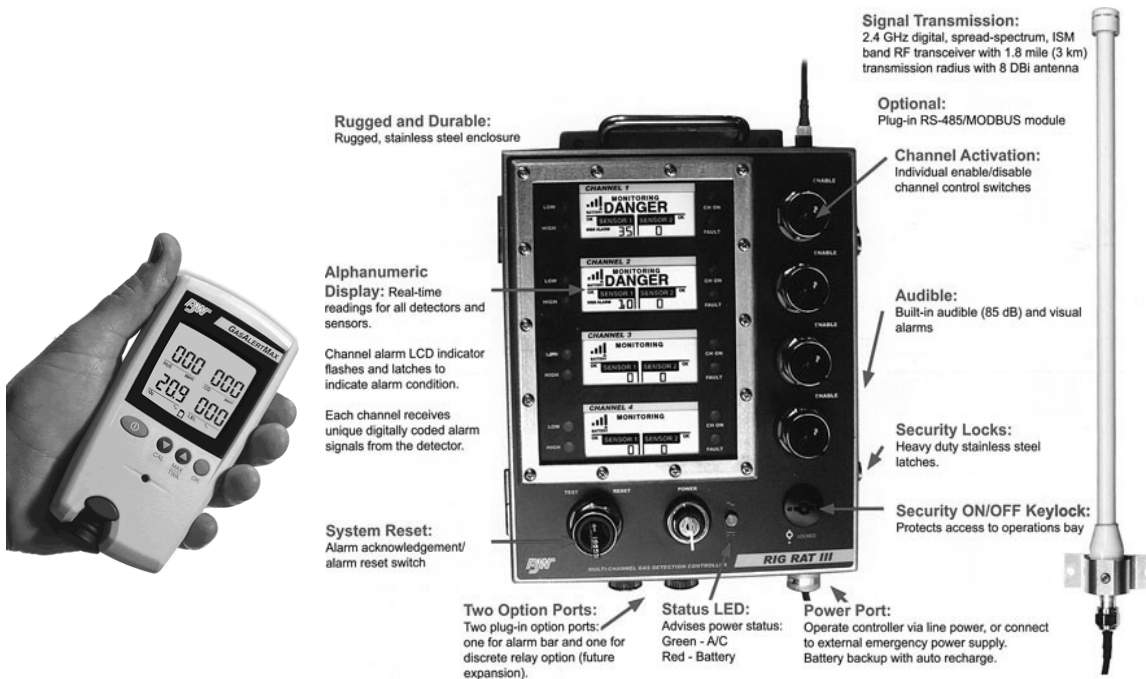
Remove the gas detector tube from the aspirating pump after the prescribed sample volume has been drawn. Read the concentration of gas at the maximum end of the stain against the printed scale on the detector tube. Some detector tubes require a temperature correction using a table or correction coefficient provided in the instructions.



Electronic Gas Detector

An electronic gas detector is a device which actively draws air in and analyzes the content of the drawn air for gases. These devices may have between 1 and 6 gas sensors. They are available in personal, portable and fixed models.

Monitoring Devices



Gas monitors are instruments that detect a gas and provide a visual or audible output according to the amount of gas sensed.

Without proper gas detection, hazardous atmospheres may significantly affect the health of an entry team. Many airborne contaminants cannot be detected by smell or vision and can only be measured with special equipment. Data gathered in the late seventies and early eighties indicated that 65% of all those who died in confined spaces were unaware that the space they were entering was a potential hazard. Over 50% of confined space deaths occur to the *rescuers* and over 33% of the fatalities occurred after the space was tested and declared safe and the gas detector was removed. In 2010 there were 99 workers exposed to chemical hazards that resulted in lost time.

Gas detectors have been around for a long time, starting with that infamous methane sniffing canary, which sadly was a one-shot device, which when subjected to methane, tended to die rather quickly with no audio and visual alarm capabilities other than a slight cheep and a total lack of motion. Fortunately, technology has advanced significantly, and we find ourselves at this point in time with some very sophisticated electronic equipment.

Selecting Sampling Devices

Depending on its sensor configuration, proper gas detection equipment can help identify the hazard and protect your workers.

For those who work in atmospheres that could be hazardous to your health, selecting the right gas detector could be the single most important decision you ever make. Your life could hinge on that decision so it is critical that the user/purchaser make him/her aware of the hazards that could be encountered and the proper sensors to protect them.

Never assume that instruments will work for specific applications without applying two important criteria:

1. You must know what to expect to find in your particular space.
2. You must ensure that the instrument you are going to purchase/use is capable of detecting these hazards.

But even the most sophisticated technology is useless if the sensors used are unable to detect the gases present.

Selecting a gas detector should be based on the hazard faced. Unfortunately, far too many purchasers make one of the largest and most crucial single equipment expenditures without really understanding what they are buying. Sensors and their capabilities are the single most important factor when choosing a gas detector, yet more often than not, decisions are based on size, price, bells and whistles and other such features that have nothing to do with the instrument's detecting abilities.

There are two categories of gas detection instruments: indirect reading and direct reading. With indirect reading instruments, samples must be sent to the laboratory for analysis: direct reading instruments provide their information at the time of sampling. Since the primary objective of gas detection in confined space operations is to *immediately warn* the entry team of adverse atmospheric changes, direct reading instruments are the only safe source of sampling information. There are several direct reading portable gas detectors on the market today.

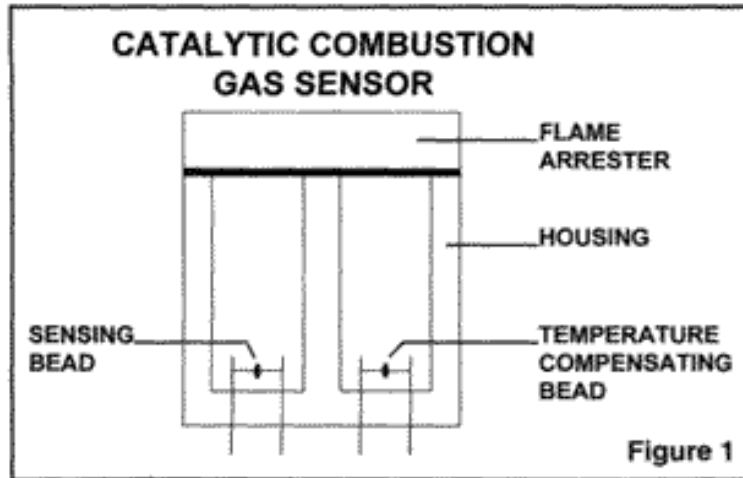
Gas detectors come in a variety of sizes, shapes, colours and sensor configurations. For confined space work, it is necessary to monitor for the three main hazards: oxygen deficiency/enrichment, combustible gases and toxics. Therefore, an instrument capable of dealing with these three issues is necessary.

Depending on its sensor configuration, proper gas detection equipment can help identify the hazard and protect your workers.

SENSOR TECHNOLOGY - Combustible Gas Sensors

Catalytic combustible gas sensors.

These sensors look for explosive atmospheres. They detect combustible gases by causing an actual combustion of gases within the sensor chamber (**Figure 1**). A catalytic sensor consists of a flame arresting material, encasing two chambers each which contains a coiled wire filament. One chamber is designed to allow air to enter it, and its coil is coated with platinum or palladium. The other chamber is sealed to prevent air from entering and the coil is not coated. Both coils are heated (to temperatures of 500 degrees F or higher). When combustible gases are exposed to the coil they will ignite and raise the temperature of the bead even higher. The temperature increase and the change of the coil's electrical resistance are displayed as "percent LEL".



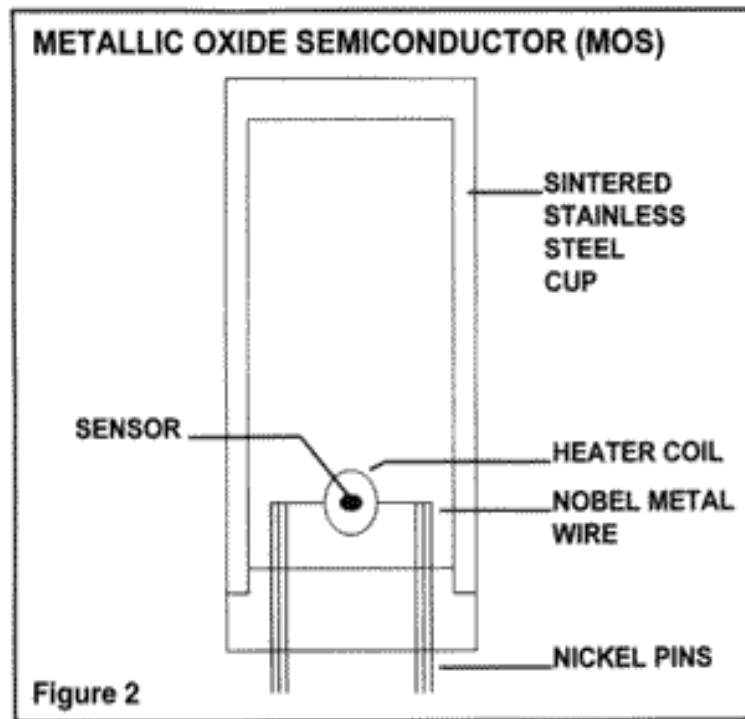
These sensors offer good linearity and can react to most combustible gases. However, as resistance change per cent LEL is quite small, they work better in concentrations between 1,000 and 50,000 PPM. They do not measure trace amounts of gas (under 200 PPM) and therefore are of no use in determining toxic levels. The disadvantages are:

- they must have a minimum of 16% oxygen content in the air to work accurately
- the sensor can be damaged by lead or silicone
- the readings can be affected by humidity and water vapour condensation
- they respond poorly to low energy hydrocarbons such as oil vapours
- they tend to lose their linearity after a year or so
- they are not recommended for use in an *acetylene* atmosphere

The flame arrester will prevent ignition of most gases *except acetylene* outside the sensor. It is extremely important to check the approvals for which type of hazardous locations the detector can function in.

Metallic Oxide Semiconductor (MOS) Combustible Gas Sensor

MOS or "Solid State" Combustible Gas Sensors consist of a housing (either a stainless-steel sintered cup or plastic) containing an electric conductor. This conductor is made up of a heating element (operating between 150 degrees F to 350 degrees F) and a bead that is proprietary mixture of metal oxides. As current travels through the bead when exposed to clean air, a base resistance is established. When a gas



comes into contact with the sensor surface, a change in sensor resistance occurs. The sensor resistance can change significantly even with small quantities of gases (less than 200 ppm). This sensor has a long operation life (3 to 5 years), is very rugged and will recover better from high concentrations of a gas that could damage other types of sensors. **(Figure 2)**

There are also disadvantages:

- MOS sensors also require oxygen to work accurately, although not as much as the catalytic
- some sensor's heating elements have a high demand for power which requires large battery packs
- the readings can be affected by humidity and water vapour condensation

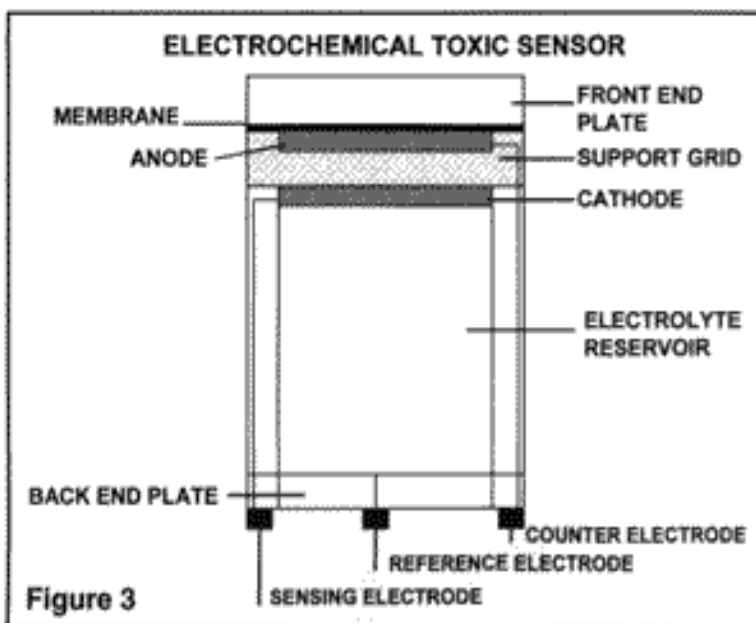
Infra-Red Combustible Sensors

Recently Infra-Red Sensors have begun appearing in some instruments. They work well in low oxygen levels or acetylene atmospheres; however, they are quite expensive. These sensors work by reflecting light off a mirror and measuring the amount of light adsorbed during refraction. Infrared sensors typically require a constant flow across the sensing assembly and may be slow to clear from alarm. They are unable to detect hydrogen.

Toxic Sensors

Electrochemical (Wet Chem) Toxic Sensors

These sensors react to a specific chemical (substance). Chemically specific sensors are available for chlorine, ammonia, carbon monoxide, carbon dioxide, nitrogen dioxide, nitric oxide, hydrogen cyanide, hydrogen sulfide, sulfur dioxide and hydrochloric acid. The manufacturer's technical information will indicate what sensors are available for their unit. (Figure 3)



The electrochemical sensor housing contains two (and sometimes three) electrodes sitting in a liquid solution (either a base or alkali, depending on what the sensor is looking for). The housing is covered by a Teflon membrane that keeps the fluid in the housing yet allows air in. As air molecules enter through the thin Teflon membrane, the fluid will react with a specific substance if found. When the detector is working, a small current passes between the two electrodes. Any change in the fluid's density caused by a reaction to the substance in the air will affect the density of the fluid and change the amount of current passing between the two electrodes. The current then passes through a temperature compensating circuit. The electron flow is then read as a specific amount of the substance. The manufacturer creates a Wet Chem Sensor's ability to detect specific types of gases based on the choice of membrane, the number of electrodes, the alloy of the electrodes, the alloy of the electrode (gold, lead, etc.) and type of electrolyte fluid.

These sensors have very good linearity which makes them very accurate for the substance they will react to. They can measure either large or small quantities and these sensors have a typical life span of approximately 1 year.

As with all sensors, Wet Chem sensors have their limitations. The fluid can freeze when left in environments having temperatures lower than 0 degrees C. They are also adversely affected by altitude. Air pressure at sea level (14.73 psi absolute) is the force required to induce the air into the sensor. As one rises in altitude, the less force is available to push the air into the sensor, thus reducing the accuracy of the reading. Some substances, (e.g. moisture) affect the sensor by changing the make up of the fluid, thus reducing the amount of electrical resistance which impacts the reading. Check the manufacturer's instructions to see which substances will affect the sensor.

Abnormal readings are another issue with regards to Wet Chem sensors. Abnormal readings are generally readings that don't make sense. For instance, you are working in a sanitary sewer and your instrument is showing a CO reading of 300 PPM (current TWA in Ontario is 35 PPM) and a low reading (below the TWA of 10 PPM) of hydrogen sulfide. What you likely have is interference from the hydrogen sulfide. Some electrochemical carbon monoxide sensors are subject to interference from low levels of hydrogen sulfide. The knowledge that carbon monoxide is not a common occurrence in sanitary sewer applications (whereas hydrogen sulfide is) would lead you to consider that you are probably having an interference problem.

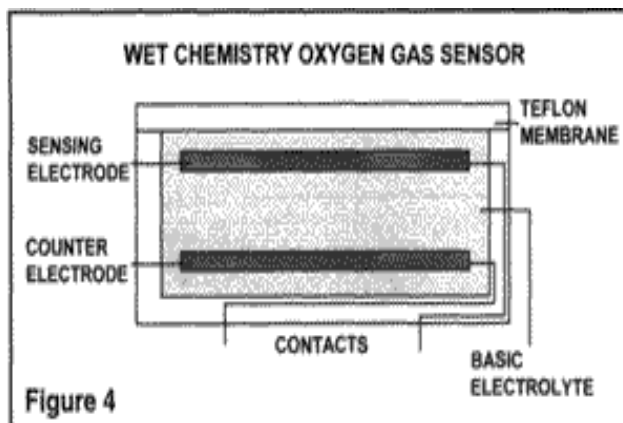
Awareness of the hazards in your workplace, some basic understanding of chemistry, knowing what interferent gases adversely affect your unit and strict testing protocols will minimize this problem.

Metallic Oxide Semiconductor (MOS) Toxic Broad Range Gas Sensors

There are a number of different MOS sensors on the market and one has been developed for detecting toxic gases. Its make-up and operation is similar to the one used for the detection of combustible gases. However, the MOS broad range toxic sensor is capable of reacting to a wide range of toxic gases including carbon monoxide, hydrogen sulfide, ammonia, styrene, toluene, gasoline and many other hydrocarbons and solvents. MOS sensors cannot detect carbon dioxide or sulfur dioxide. The sensor is incapable of telling you what gas you have encountered or the concentration, only that the atmosphere may be hazardous to your health.

Oxygen Sensors

Oxygen sensors are the only true chemically-specific sensors (Figure 4). They are similar to the electrochemical (Wet Chem) sensors described previously. These sensors have very good linearity, which makes them very accurate for the substance they will react to. They can measure either large or small quantities and these sensors have a typical life span of approximately 1 year for many toxic gases and up to two years for hydrogen sulfide and carbon monoxide.



However, they are also susceptible to freezing, and are affected by altitude and pressure.

Never use an oxygen sensor to detect toxic gases. It is true that a toxic gas will displace the oxygen in a confined space. However, it takes 60,000 PPM of *any* gas to lower the oxygen from 20.9% (normal) to 19.5% (alarm point). More importantly, 60,000 PPM of any toxic gas will *kill* you.

Personal Monitors

Personal gas monitors are typically light weight devices worn by the worker. These monitors are available in a variety models and may have between one and six sensors. At times, these devices may be referred to as a portable or placed monitors. Under these circumstances, portable and placed refer to the fact the monitor is no longer being worn by a worker and has been placed at a temporary location to perform gas monitoring.

Portable Monitors

Many manufacturers have integrated several gas sensors into one detector device. The multi-gas detector has the capabilities of sampling the atmosphere for several gases at the same time. For example: combination of flammable vapours, H₂S, CO, O₂, methane, etc. These monitors may be worn by workers or placed at a temporary location to perform gas monitoring.

Fixed Gas Monitors

Fixed gas monitors are used to provide a constant monitoring of an enclosed area for atmospheric hazards. Fixed gas monitors are used in gas plant operations, gas batteries, and compressor stations and pump houses etc.

The system provides a comprehensive area-wide controller/sensor system for monitoring combustible gas, oxygen deficiency and toxic gases to maintain safety in a work area. A fixed monitoring system is capable of sampling for one or more gases simultaneously.

The system should contain the following components:

- **Sampling System**
- **Enclosure for monitor system**
- **Sensors**
- **Electronic Circuits**
- **Electronic Alarms**
- **Display**
- **Power Supply**

Sampling System

The sampling system is in reference to the means in which the atmosphere is drawn into the gas sensors. This is usually either a passive or an active sampling system.

Active sampling occurs when the atmosphere is actively drawn into the detector device; usually through a mechanical or manual pump, to the sensors.

Passive sampling occurs through the diffusion of gases into the gas sensors. Gas sensors are directly exposed to the atmosphere and the sample diffuses to the sensor elements.

Enclosure for monitor system

Due to some of the conditions a fixed monitoring system can be exposed to, it is important that the housing for the monitor be rugged and weather resistant. This includes resistant to sun, rain dusts and other contaminants in the air. Further, the housing should be able to withstand dropping or jarring of the instrument.

Sensors

The three main components of a gas detection system are the **active filament**, the active bead where the combustible gas burns; the **reference filament**, the filament that compensates for changes in ambient conditions; and the **flame arrestor**, whose function is to dissipate the internal heat generated by the burning of combustible gases within the sensor.

Flame arrestors are designed to be operated in atmospheres containing less than 23% oxygen. Higher concentrations of oxygen will cause the burning of combustible gases to be excessively hot; resulting in the creation of a possible ignition source.

Electronic Circuits

The electronic circuitry is the means by which a message is sent from the sensor to the alarming and display system. Information provided must be reliable and useful as life and death decisions can be made based on the data provided. The electronics' response time, accuracy, precision, radio frequency (RF) interference, reading drift and sensitivity are all factors that can differentiate a poor purchase from a good investment.

Electronic Alarms

Today's gas monitoring systems should have both audible and visual alarms. These alarms need to be loud enough or bright enough to alert the workers. As a result, many newer personal monitors also have a vibratory alarming system. If possible, alarms should sound both at the hazardous space and at a remote location where a control operator is stationed.

Display

The results of gas sampling need to be displayed on the monitor. The display should be bright enough to be read in any amount of light. The display should also indicate if an error or other complication has affected the monitor.

Power Supply

The power supply to electronic monitors is dependent upon the type of monitor. A portable monitor will usually be powered by batteries; the battery should be capable of providing power for at least 10 – 12 hours. Some disposable monitors can even supply power for up to 2 years.

A fixed gas monitoring system is typically hard wired and will provide power as long as necessary.

Electronic Monitoring Devices – Issues

A variety of issues concerning electronic gas monitors have been brought to light. The concerns regarding the operation of monitors and their readings include:

- Temperature extremes
- Oxygen content of the gas stream
- Exposure to condensed moisture
- Unnecessary exposure to high gas concentrations
- Exposure to dust
- Exposure to catalytic sensor poisons, and
- Radio Frequency Interference (RFI)

Always refer to the specific manufacturer's operating manual to understand the possible limitations.

Temperature extremes

Even though there may be a need to operate electronic monitors in a range of temperatures, the operating range of a gas monitor is typically between -20 °C and +50°C. Sampling environments beyond these temperature ranges may have an effect on the operation of the monitor.

Never store gas monitors in cold temperatures. Before testing, always ensure the monitor has stabilized to the temperature of the atmosphere being tested.

Oxygen content of the gas stream

Oxygen is required for adequate sensor operation. Even though an oxygen content of about 10% is required to obtain a valid combustible gas reading, it is recommended that any concentration below 19.5% be investigated.

Exposure to condensed moisture

Exposure to moisture while operating a gas monitor can have several detrimental affects. These may include;

- Exposure to condensed moisture will cause sensor filaments to short circuit or fracture due to thermal shock, resulting in an immediate failure.
- A short duration exposure to steam is not a problem unless the water condenses to droplets.
- Exposure to moisture may also occur when drawing a sample from a hot environment to a cold sensor. A moisture trap should be used.

Exposure to high gas concentrations

The operating range of a combustible gas monitor is between 0% - 100% of the L.E.L. Exposure to concentrations above this level will shorten the life of the sensor.

Several manufacturers have installed a limiting device in their monitor's that will disconnect the power to the sensor if exposed to high concentrations, preventing permanent failure.

Exposure to excessive dust

Excessive dust can slow or block the gas sensor filters and sampling lines. A filtering device should be used where high concentrations of dust may be present.

Exposure to catalytic sensor poisons

A catalytic sensor poison adheres and covers a sensor. Several cleaning solvents and lubricants can act as poisons. Further:

- Compounds containing chlorine or sulphur may leave a deposit on and/or corrode the active filament.
- Silicone compounds occupy the catalytic sites on the active filament and will render it inert over time.

Immediately perform a function test or calibration of the gas monitor if exposed to a poison.

Radio Frequency Interference (RFI)

If a gas monitor goes into an alarm setting when there is no gas present, this may be as a result of RFI from portable 2-way radios and cell phones. Some manufacturers have installed RFI barriers in the monitor, but they may not be perfect. If a gas monitor alarms, treat it as if a leak has occurred and react accordingly.

To test for RFI, simply activate the radio next to the monitor while in a safe environment. Generally, try to keep portables and other sending devices away from electronic monitors.

Care and Preparation of Gas Monitors

Bump Tests vs. Full Calibration

There are two methods of verifying instrument accuracy: a functional or bump test and a full calibration, each appropriate under certain conditions. A bump test verifies calibration by exposing the instrument to a known concentration of test gas. The instrument reading is compared to the actual quantity of gas present (as indicated on the cylinder). If the instrument's response is within an acceptable tolerance range of the actual concentration, then its calibration is verified. Instruments should be "zeroed" before the bump test in order to give a more accurate picture of the bump test results. When performing a bump test, the test gas concentration should be high enough to trigger the instrument alarm.

If the bump test results are not within the acceptable range, a full calibration must be performed. A full calibration is the adjustment of the instrument's reading to coincide with a known concentration (generally a certified standard) of test gas. In most cases, a full calibration is only necessary when an instrument fails a bump test or after it has been serviced. The full calibration and bump test should be conducted in a known clean fresh air environment.

When to Bump Test and When to Calibrate

In the past, there often has been confusion regarding proper calibration procedures and frequency. To clarify this issue, the International Safety Equipment Association (ISEA) issued a position statement on instrument calibration that states, "A bump test or full calibration of direct-reading portable gas monitors should be made before each day's use in accordance with manufacturer's instructions, using an appropriate test gas." If the instrument fails a bump test, it must be adjusted through a full calibration before it is used.

Function (“Bump”) Test

In order to determine if a gas monitor is working properly, a field test known as a function test or a “bump test” should be performed. To perform a function test of a gas monitor, the monitor will be subjected to a known concentration of a calibration gas. If the monitor responds in accordance with the test gases, the monitor is deemed suitable for use and may be put into service.



If the monitor responds outside the parameters of the test gases, the unit should be removed from service and inspected and re-calibrated by an authorized person.

A gas monitor should respond to within +/- 10% of the LEL value equivalent to the % volume listed on the test gas cylinder, as long as the monitor was calibrated to that gas. Always ensure the function tests are performed in a known clean air environment.

The following table outlines a basic function test procedure. Always follow the manufacturer’s specific instructions on the use, care and maintenance of electronic gas monitors.

<u>STEP</u>	<u>DESCRIPTION</u>
1. Check the record log	✓ Check the status and past history of the monitor
2. Prepare the monitor	<ul style="list-style-type: none"> ✓ Carry out pre-use inspection by visually inspecting monitor for damage, missing components and cleanliness. ✓ Turn power on and warm up the monitor. Follow manufacturer’s instructions. ✓ Check battery ✓ Carry out leak test (active monitor)
3. Zero monitor	✓ Follow manufacturer’s instructions.
4. Check monitor response to test gas	<ul style="list-style-type: none"> ✓ Flow test gas to monitor sensor (ensure test gas same as calibration gas) ✓ Observe reading (must be within +/- 10% LEL of the value listed on test gas cylinder)
5. Record function test	<ul style="list-style-type: none"> ✓ Use a record book and include: <ul style="list-style-type: none"> ○ Make, model and serial number of the monitor. ○ Expected and actual test results ○ 1st and 2nd alarm set points ○ Operator name and initials

Monitors that fail the test procedure should be removed from service and serviced by an authorized person.

The following is an example of a Function Test log.

Make: _____ Model: _____							
Serial Number: _____ Calibration Gas: _____ Date: _____							
Date	Test Gas	Test Results		Alarms		User Name	Initials
		Expected	Actual	1 st	2 nd		

The following table offers guidelines for performing function tests:

EXPECTED USE	FREQUENCY (minimum)
Daily Use	✓ At start of work shift
Scheduled Hazardous Operation	✓ 24 hours before use
After Rough Treatment	✓ Send for inspection and calibration
Emergency Response	✓ Monthly and prior to use



Calibration

Gas monitoring instruments are designed to protect personnel from unseen hazards that may exist in workplace environments, including confined spaces. It is vital to worker safety that these instruments are maintained and calibrated properly. Instrument inaccuracy due to improper or irregular calibration can lead to serious accidents. The only way to guarantee that an instrument will detect gas accurately and reliably is to test it with a known concentration of gas.

The responsiveness of electrochemical sensors will vary with environmental conditions. Sensor response will be different (lower or higher) depending on the actual environmental conditions. Therefore, as much as possible, the monitors should be calibrated at environmental conditions that are the same as (or similar to) actual field conditions. Calibration at locations where the equipment is to be used is always preferable.

Most instruments are equipped with two levels of alarms – warning and danger. The warning alarm alerts the user that the environment has a detectable concentration of gas and is therefore potentially hazardous. The danger alarm indicates that the gas concentration exceeds the programmed “hazard” threshold, and the area is approaching a hazardous level. Whether an instrument warns and/or alarms at the proper time depends on its detection abilities and its ability to translate its findings into an accurate reading.

If the instrument’s reference point has shifted, the reading will shift accordingly and be unreliable. This is called “calibration drift” and it happens to all detectors over time. An instrument that experiences calibration drift can still measure the quantity of gas present, but it cannot convert this information into an accurate numerical reading. Regular calibration with a certified standard gas concentration will update the instrument’s reference point, ensuring that the instrument will produce continued, accurate readings.

Causes of Calibration Drift

Over time, the accuracy of gas detection instruments can diverge from their calibration settings in several ways:

- Gradual chemical degradation of sensors and drift in electronic components that occur naturally over time.
- Chronic exposures to, and use in, extreme environmental conditions, such as high/low temperature and humidity, and high levels of airborne particulates.
- Exposure to high (over-range) concentrations of the target gases and vapours.
- Chronic or acute exposure of catalytic hot-bead LEL sensors to poisons and inhibitors. These include volatile silicones, hydride gases, halogenated hydrocarbons, and sulphide gases.
- Chronic or acute exposure of electrochemical toxic gas sensors to solvent vapours and highly corrosive gases.
- Harsh storage and operating conditions, such as when an instrument is dropped onto a hard surface or submerged in liquid. Normal handling/jostling of the equipment can create enough vibration or shock over time to affect electronic components & circuitry.

Often, after exposure to the more extreme conditions above, when calibration is attempted, the detector will either display a failure message or it will not allow the user to fully adjust the display reading. At this point, the severely damaged sensor must be replaced and/or the detector serviced by qualified personnel.

Correctly calibrating an instrument helps to ensure that the instrument will accurately respond to the gases that it is designed to detect, warning users of hazardous conditions before they reach dangerous levels. In addition to detecting and correcting for calibration drift, regular calibration assures the user that the instrument is functional. Gas detection instruments are often subjected to harsh operating and storage conditions where they can be damaged. Both of these factors can affect instrument performance, leading to inaccurate readings or even instrument failure. While a unit may appear to be sound during a visual inspection, it actually could be damaged internally. Regular calibration is the only way to be certain that a detector is fully functional. Moreover, a standing policy for regular calibration sets the tone for a safety-conscious work environment and indicates to workers that safety is a priority. As a result, workers may be more likely to keep safety principles in mind throughout the workday.

A written record of calibration should be kept for the life of each instrument. This record allows users to quickly identify an instrument that has a history of excessive maintenance/repair or is prone to erratic readings.

Calibration Rules

The following are a few basic instrument calibration rules to ensure a clear path to health and safety.

- Follow the manufacturer's guidelines for proper calibration. The type and concentration of calibration gas, sample tubing, flow regulators and calibration adapters are key links in the calibration chain. Using equipment provided by the original manufacturer should ensure a proper start to every calibration.
- Only use certified calibration gas before its expiration date. The most important tool used in calibration is the gas itself. The instrument can only be as accurate as the gas used to calibrate it. The concentration of calibration gas, particularly the concentration of reactive gases such as hydrogen sulphide or chlorine, will only remain stable for a finite period of time. Never use calibration gas after its expiration date.
- Train workers on the proper methods of calibration. Everyone responsible for performing instrument calibration should be trained and tested accordingly.

The following table outlines a possible calibration strategy for combustible gas monitors:

EXPECTED USE	CALIBRATION GAS
Sampling a specific vapour	✓ Calibrate to that vapour
General purpose; where flammable gas is primarily methane	✓ Calibrate to methane
General purpose, where methane is a minor component (If present)	✓ Calibrate to propane or hexane

Methane is one of the most difficult combustible gases to burn at the active filament. Eventually, a sensor may lose sensitivity to methane, but still respond to other gases such as propane.

Therefore, a combustible gas monitor that is used as a general-purpose monitor may potentially be used to monitor methane and **MUST** be calibrated to methane. Failure on the part of the monitor to detect methane may result in the operator being unable to monitor a significant portion of a combustible gas mixture because of its loss of sensitivity to methane, with potentially serious consequences.

Assuming correct testing procedures, a sensor that responds to methane will normally respond to other combustible gases. However, a sensor that responds to other combustible gases will not necessarily respond to methane when nearing the end of its operating life.

NOTES: _____



Hazard Assessment

As outlined in Safety Legislation, an employer must assess a work site and identify existing and potential hazards before work begins at the work site. If an existing or potential hazard to workers is identified during a hazard assessment, an employer must take measures in accordance with this section to eliminate the hazards, or if elimination is not reasonably practicable, control the hazard.

If reasonably practicable, an employer must eliminate or control a hazard through the use of engineering controls. If a hazard cannot be eliminated or controlled the employer must use administrative controls that control the hazard to a level as low as reasonably achievable.

If the hazard cannot be eliminated or controlled, the employer must ensure that the appropriate personal protective equipment is used by workers affected by the hazard.

If the hazard cannot be eliminated or controlled, the employer may use a combination of engineering controls, administrative controls or personal protective equipment if there is a greater level of worker safety because a combination is used.

In regards to atmospheric sampling for hazards, there are two primary types of assessments that are used; these are **Qualitative and Quantitative** assessments.

Qualitative Assessment are those assessments done by a worker who uses his knowledge, experience, and his senses to determine if a leak has occurred which may create a hazardous atmosphere. This type of test does not provide a measurement of a gas in air, but it will be the mechanism necessary to provide a Quantitative assessment. For example: if a worker suddenly hears an abnormal high-pressure leak in a gas plant, he should assume a problem has occurred and take the appropriate steps.

Quantitative Assessments are those assessments done with sophisticated electronic gas detection equipment to get an actual reading of an atmosphere. This assessment will lend support to the verification of whether an actual atmospheric hazard exists.

As outlined earlier, the purpose of atmospheric sampling is to determine whether a hazardous atmosphere exists. With this in mind, there are two types of sampling that occur, **intermittent sampling and continuous sampling**.

Intermittent sampling is just that; sampling that occurs at different times and at different locations of a work place. This type of sampling can be performed on a specific schedule, when conditions change, or when a job function changes.

Continuous sampling of an atmosphere occurs constantly through out the time that a gas monitor is in operation in a space. The value of this type of sampling is in its ability to provide actual atmospheric readings in real time. This type of sampling will identify trends in atmospheric changes.

Sampling strategies

Two types of gas sampling strategies are suggested; these are the **Matrix or Grid Strategy** and the “**Spoke and Wheel**” **Strategy**.

The type of sampling required is dependent upon:

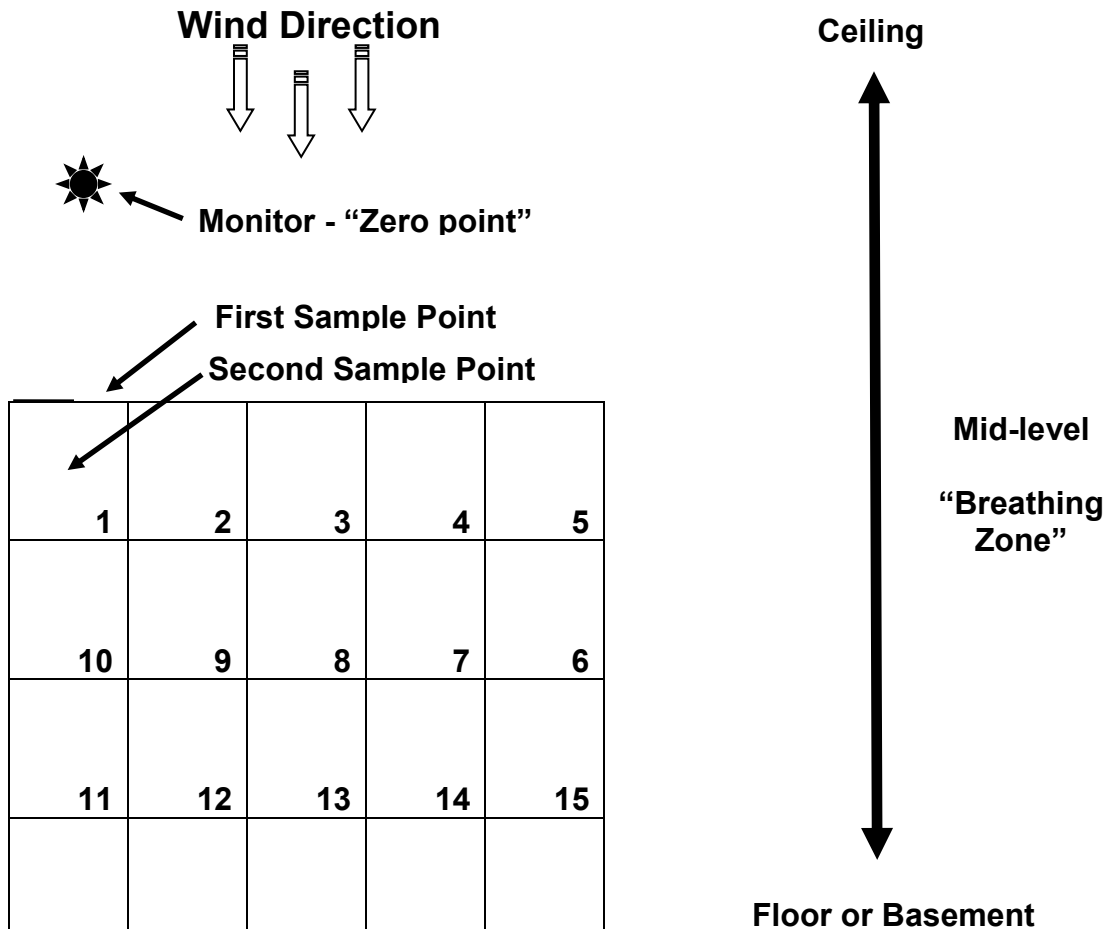
- The work being performed
- Potential interferences from adjacent work areas
- Types of monitors in use
- The ability of the operator to interpret the information after it's gathered
- The need for all the information

If an operator decides that a combustible gas monitor is required to sample the atmosphere, they will need to:

1. select the appropriate monitor (passive or active)
2. function test the monitor
3. determine sampling strategy and starting point
4. perform the sampling strategy in an organised manner
5. record the readings
6. interpret the information

The **matrix strategy** incorporates the use of a floor or plot plan with very specific, defined areas. Each area will be sampled and recorded and used as a base line for future sampling. Ensure the whole space is measured because gases with varying vapour densities may be present. Both strategies require the monitors to be activated or “Zeroed Out” in a known fresh air environment.

Follows is a sample matrix strategy:

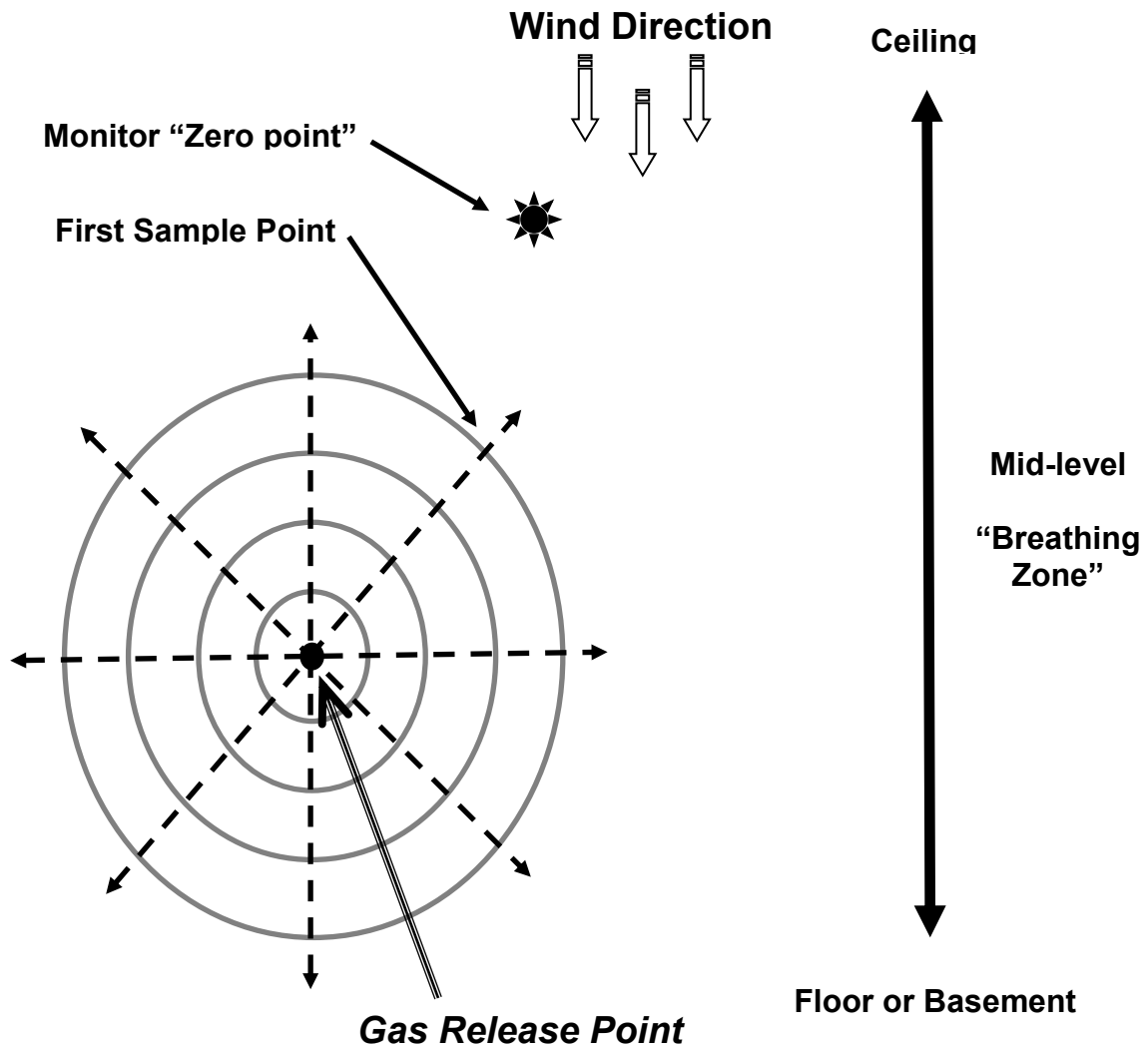


NOTES: _____



The “**Spoke and Wheel**” strategy is used when the source of gas release is known, or suspected. The strategy incorporates an encircling pattern with the starting point at a safe distance upwind of the release point. A plot plan is used with specific locations measured out in the shape of a wheel with spokes. The hub of the wheel is referred to as the leak location.

Follows is an example of the “spoke and wheel” strategy:



Operational range of gas monitors

Safety Legislation states that a worker shall not occupy a hazardous space unless adequate protection is provided. Monitors are part of requirements necessary to protect a worker; they are designed to sample the atmosphere and warn if levels are exceeded.

Monitors have an operational range of the amounts of vapours deemed hazardous. For example; a worker would not like to work within a gas's explosive range; nor anywhere the explosive range! In fact, safety legislation states that a worker shall not occupy a space with more than 20% of a gases LEL. Moreover, some workplaces have increased their standards to 10% of a gases LEL.

A gas monitor needs to be calibrated for the gas it is sampling for; otherwise the sample reading may not be accurate. For example, if the atmospheric hazard is suspected to be methane, the monitor should be calibrated to methane.

Flammable Vapours

Vapours that have collected into a combustible range are dangerous if allowed to contact a sufficient heat source. Reducing vapour concentration will help keep an atmosphere from combusting.

The following chart outlines a variety of gases with their explosive concentrations and their safe working concentrations:

Vapour	10 % of LEL	20 % of LEL	100% of LEL	UEL
Methane	0.5 %	1 %	5 %	15 %
Ethane	0.6 %	1.2 %	3 %	12.5 %
Propane	.23 %	.46 %	2.3 %	9.5 %
Pentane	.15 %	.3 %	1.5 %	7.8 %
Butane	.19 %	.38 %	1.9 %	8.5 %
Hexane	.12 %	.24 %	1.2 %	7.5 %
Toluene	.13 %	.25 %	1.27 %	7.0 %
Hydrogen	.4 %	.8 %	4 %	74 %
Hydrogen Sulfide	.4 %	.8 %	4 %	44 %
Carbon Monoxide	1.25 %	2.5 %	12.5 %	74 %

Hot Work Processes may create additional hazards that **Cold Work** may not. Hot work processes include the creation or use of possible ignition sources. These include the use of non-classified electrical equipment, internal combustion engines, and other work such as cutting, welding, burning, drilling and grinding.

Cold Work Processes is work that is performed that does create or use possible ignition sources.

The following table outlines a suggested target work range and sampling schedule:

Target Concentration	Cold Work	Hot Work
0 % LEL	Ideal, Intermittent Sampling	Ideal, Continual Sampling
1 % to 9 % LEL	Continual Sampling	Continual Sampling
10 % to 19 % LEL	Continual Sampling with B.A.	No Hot Work
20 % LEL	Emergencies Only	No Hot Work

When flammable gases are less than 10% LEL, occupational exposure levels of other materials may be exceeded and therefore respiratory protection needed.

Toxic vapours

Toxic Vapours in excessive concentrations may cause a variety of poisoning effects ranging from severe, acute effects to severe long-term effects. It's important to identify which toxic atmospheres may be found in your work place and the specific location at which a release may occur.

Government agencies set limits for worker exposure to toxic substances. Toxic contaminants in air are considered safe as long as they stay below certain levels of concentration. These levels are known as

- **Occupational Exposure Limits (OEL's)**
- **Threshold Limit Values (TLV's)**
- **Permissible Concentrations (PC's)**

Time Weighted Average (TWA) is the maximum exposure level for an 8 hour day.

Short Term Exposure Limit (STEL) is acceptable for exposures no longer than 15 minutes in duration. Each exposure must be separated by at least 60 minutes on no exposure.

Occupational Exposure Limit Ceiling or 8 Hour Occupational Exposure Limit is the maximum concentration of a gas that an employee can be exposed to before the worker must immediately evacuate or don breathing apparatus.

IDLH – Immediately Dangerous to Life and Health. This is a concentration at which healthy worker can suffer the adverse health effects if exposed for a duration lasting up to 30 minutes.

The technical information outlining the hazards of a material can be found in specific *MSDS*'s.

Oxygen Levels

The air we breathe normally contains about 21% oxygen. Gases used in purging, such as nitrogen and carbon dioxide may cause lack of oxygen. Other causes could include certain processes and work procedures such as welding.

The Labour Board of Canada, Alberta OH&S Acts or Compensation Boards have strict guidelines to be followed when dealing with the oxygen content in any space that a worker may enter. A worker should not enter any area unless a breathing quality of air can be supplied, or respiratory equipment must be worn.

The following table outlines the effects of varying concentrations of oxygen.

Oxygen Concentrations	Effects
23% and above	Increased flammability of materials. Entry is not allowed.
21%	Ideal.
20.9%	Normal.
18 – 19.5%	Minimum required to maintain safe working conditions. Consult provincial regulations.
16%	Increased pulse, no coordination, some impairment of thinking.
14%	Very poor judgement and co-ordination, may cause poor respiration that can lead to permanent heart damage.
Less than 12%	Nausea, vomiting, loss of consciousness, convulsions and death.

Correction Factors

A correction factor is a simple ratio of a monitor response to a known hydrocarbon gas, compared to the gas it was calibrated to; usually methane. Once the correction factor is known, multiply the monitor reading by the correction factor to obtain the actual gas concentration.

It is a common error to use the wrong monitor for a case. In a recent case from Alberta OH&S, a methane calibrated monitor was used to read the LEL of gasoline vapor. The monitor gave a reading of 14% LEL when in reality it was 73%.

Multiplier accuracy is +/-25%, subject to change without notice pending additional testing. If the sensor is used in atmospheres containing unknown contaminants (silicones, sulfur, lead, or halogen compound vapors) methane is the recommended calibration gas. Periodic comparison of methane and pentane readings is recommended when using this chart.

The correction process and calculation would be valuable if all combustible gases burned the same on the active filament of a catalytic sensor and all monitors reacted in the same manner. However, they don't. Furthermore, each manufacturer's formulation of active / reference filaments responds in a unique manner to the combustible gases. The following table offers a look at some of the manufacturer's correction factors.

Combustible Vapour	Methane Correction Factor
Methane	1.0
Propane	1.1
Hydrogen	.06
Hexane	1.6
Toluene	1.4

Many people advocate the application of correction factors in an effort to obtain a more "accurate" combustible gas reading. A combustible gas monitor is only "accurate" if one is working with a single combustible gas in the air and the monitor is calibrated for that gas.

Some limitations of correction factors to combustible gas readings are as follows:

- To apply correction factors properly, the operator must have knowledge of the composition of the atmospheric gases and concentrations.
- Correction factors are for relatively new sensors. As sensors age, their correction factor changes.
- The age of the sensor is based on usage, not time.
- Many published correction factors are only theoretical and have not been determined by experiment.



Section 3

Control Methods for Hazardous Vapours





This section discusses the three main types of controls to be used when an identified hazard cannot be eliminated from a work activity or a work environment.

Learning Objectives:

1. Identify the three types of hazard controls
2. Be familiar with the four main Engineering Controls
3. Be familiar with the different types of Administrative Controls
4. Be familiar with the main types of Personal Protective Equipment (PPE)

Introduction

As safety laws state, an employer must assess a work site and identify existing and potential hazards before work begins at the work site.

If an existing or potential hazard to workers is identified during a hazard assessment, an employer must take measures to:

- (a) eliminate the hazards, or
- (b) if elimination is not reasonably practicable, control the hazard.

If reasonably practicable, an employer must eliminate or control a hazard through the use of engineering controls.

If a hazard cannot be eliminated or controlled, the employer must use administrative controls that control the hazard to a level as low as reasonably achievable.

If the hazard cannot be eliminated or controlled, the employer must ensure that the appropriate personal protective equipment is used by workers affected by the hazard.

If the hazard cannot be eliminated or controlled, the employer may use a combination of engineering controls, administrative controls or personal protective equipment if there is a greater level of worker safety because a combination is used.

The purpose of atmospheric hazard assessments is to determine if an unacceptable level of hazard exists in the atmosphere. However, this is only part of the full formal hazard assessment.

Engineering controls

Engineering controls is the best method of controlling a hazard since involves the removal or engineering out of a hazard. Engineering controls include one or more of the following:

- ✓ Eliminate the hazard from the worker
- ✓ Substitute for a lesser hazard to reduce the risk of exposure
- ✓ Isolate product from the worker
- ✓ Isolate the worker from the product

Administrative controls

Administrative controls are methods of controlling employee exposures to contaminants by identifying appropriate work actions and behaviours. Administrative controls include:

- ✓ Developing **safe work procedures** to control emissions, limit the duration of worker exposure, and selecting appropriate workers for the job.
- ✓ **Monitoring staff** to ensure policies are followed.
- ✓ Providing **worker training** and using only qualified and competent workers for hazardous work.
- ✓ Following a **preventative maintenance program** which includes regular inspections.

Personal Protective Equipment

After engineering and administrative controls, PPE is used as the last line of defence. As such a worker's PPE needs to be maintained in good condition. This includes following the manufacturer's recommendations for the use and the limitations of the equipment. It also includes following the manufacturer's specifications on the maintenance of the equipment.

In addition, the many types of PPE available, all PPE must be suitable to the task and fitted properly. For our purposes, we will concentrate on the use of Fire-Retardant Work wear (FRI) and Breathing Apparatus.

Fire Retardant Work-wear (FRW)

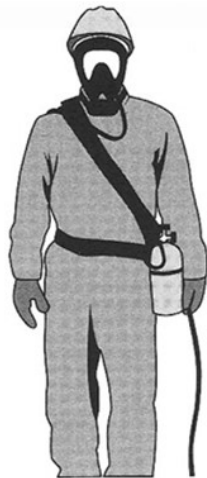
Workers who may be required to work in a potentially flammable atmosphere are required by legislation to wear FRW. This type of PPE must be non-flammable,

will not melt, and does not cause a build up of static electricity. The two common types of clothing used is either constructed of flame-resistant cloth and thread or clothing that is coated with flame retardant material.

Respiratory Protective Equipment

The two types of respiratory protection used in the petroleum industry for the protection of workers are Self Contained Breathing Apparatus (SCBA) and Supplied Air Breathing Apparatus (SABA).

SCBA



Supplied Air Breathing Apparatus (SABA)

SABA



Self Contained Breathing Apparatus (SCBA)

Both types of breathing apparatus must be under positive pressure in the face piece for use in the oil industry. This helps to protect the worker in the event of a face mask seal breach.

Positive Pressure Breathing Apparatus is required:

- When oxygen concentrations in the atmosphere is less than 19.5%
- When atmospheric contaminants are considered to be immediately dangerous to life and health
- When atmospheric contaminants are unknown
- When concentrations of atmospheric contaminants are unknown
- When the exposure levels of the contaminant are lower than the warning properties.

Any time a worker is expected to wear respiratory protection, the employer shall have a code of practise in place to ensure that wearers are doing so in accordance to legislation and the manufacturer's specifications.



Appendix 1

Related Legislation





Occupational Health and Safety Act – Alberta

Obligations of employers, workers, etc.

2(1) Every employer shall ensure, as far as it is reasonably practicable for the employer to do so,

- (a) the health and safety of
 - (i) workers engaged in the work of that employer, and
 - (ii) those workers not engaged in the work of that employer but present at the work site at which that work is being carried out, and
- (b) that the workers engaged in the work of that employer are aware of their responsibilities and duties under this Act, the regulations and the adopted code.

(2) Every worker shall, while engaged in an occupation,

- (a) take reasonable care to protect the health and safety of the worker and of other workers present while the worker is working, and
- (b) co-operate with the worker's employer for the purposes of protecting the health and safety of
 - (i) the worker,
 - (ii) other workers engaged in the work of the employer, and
 - (iii) other workers not engaged in the work of that employer but present at the work site at which that work is being carried out.

(3) Every supplier shall ensure, as far as it is reasonably practicable for the supplier to do so, that any tool, appliance or equipment that the supplier supplies is in safe operating condition.

(4) Every supplier shall ensure that any tool, appliance, equipment, designated substance or hazardous material that the supplier supplies complies with this Act, the regulations and the adopted code.

(5) Every contractor who directs the activities of an employer involved in work at a work site shall ensure, as far as it is reasonably practicable to do so, that the employer complies with this Act, the regulations and the adopted code in respect of that work site.

Prime contractor

3(1) Every work site must have a prime contractor if there are 2 or more employers involved in work at the work site at the same time.

(2) The prime contractor for a work site is

(a) the contractor, employer or other person who enters into an agreement with the owner of the work site to be the prime contractor, or

(b) if no agreement has been made or if no agreement is in force, the owner of the work site.

(3) If a work site is required to have a prime contractor under subsection (1), the prime contractor shall ensure, as far as it is reasonably practicable to do so, that this Act and the regulations are complied with in respect of the work site.

(4) One of the ways in which a prime contractor of a work site may meet the obligation under subsection (3) is for the prime contractor to do everything that is reasonably practicable to establish and maintain a system or process that will ensure compliance with this Act and the regulations in respect of the work site.

NOTES: _____

Occupational Health and Safety Code 2017

Part 2 Hazard Assessment, Elimination and Control

Hazard assessment

7(1) An employer must assess a work site and identify existing and potential hazards before work begins at the work site or prior to the construction of a new work site.

7(2) An employer must prepare a report of the results of a hazard assessment and the methods used to control or eliminate the hazards identified.

7(3) An employer must ensure that the date on which the hazard assessment is prepared or revised is recorded on it.

7(4) An employer must ensure that the hazard assessment is repeated

(a) at reasonably practicable intervals to prevent the development of unsafe and unhealthy working conditions,

(b) when a new work process is introduced,

(c) when a work process or operation changes, or

(d) before the construction of significant additions or alterations to a work site.

Worker participation

8(1) If reasonably practicable, an employer must involve affected workers in the hazard assessment and in the control or elimination of the hazards identified.

8(2) An employer must ensure that workers affected by the hazards identified in a hazard assessment report are informed of the hazards and the methods used to control or eliminate the hazards.

Hazard elimination and control

9(1) If an existing or potential hazard to workers is identified during a hazard assessment, an employer must take measures in accordance with this section to

(a) eliminate the hazards, or

(b) if elimination is not reasonably practicable, control the hazard.

9(2) If reasonably practicable, an employer must eliminate or control a hazard through the use of engineering controls.

9(3) If a hazard cannot be eliminated or controlled under subsection (2), the employer must use administrative controls that control the hazard to a level as low as reasonably achievable.

9(4) If the hazard cannot be eliminated or controlled under subsections (2) or (3), the employer must ensure that the appropriate personal protective equipment is used by workers affected by the hazard.

9(5) If the hazard cannot be eliminated or controlled under subsections (2), (3) or (4), the employer may use a combination of engineering controls, administrative controls or personal protective equipment if there is a greater level of worker safety because a combination is used.

Emergency control of hazard

10(1) If emergency action is required to control or eliminate a hazard that is dangerous to the safety or health of workers,

(a) only those workers competent in correcting the condition, and the minimum number necessary to correct the condition, may be exposed to the hazard, and

(b) every reasonable effort must be made to control the hazard while the condition is being corrected.

10(2) Sections 7(2) and 7(3) do not apply to an emergency response during the period that emergency action is required.

Health and safety plan

11 If ordered to do so by a Director, an employer must prepare and implement a health and safety plan that includes the policies, procedures and plans to prevent work site incidents and occupational diseases at the work site.

Part 5 Confined Spaces

Code of practice

44(1) An employer must have a written code of practice governing the practices and procedures to be followed when workers enter and work in a confined space.

44(2) The code of practice must:

- (a) take into account and apply the requirements of this Part and section 169,
- (b) be maintained and periodically reviewed, and
- (c) identify all existing and potential confined space work locations at a work site.

44(3) A worker involved in any aspect of a confined space entry must comply with the requirements and procedures in the code of practice.

Hazard assessment

45 If a worker will enter a confined space to work, an employer must appoint a competent person to:

- (a) assess the hazards the worker is likely to be exposed to while in the confined space,
- (b) specify the type and frequency of inspections and tests necessary to determine the likelihood of worker exposure to any of the identified hazards,
- (c) perform the inspections and tests identified,
- (d) specify the safety and personal protective equipment required to perform the work, and
- (e) identify the personal protective equipment and emergency equipment to be used by a worker who undertakes rescue operations in the event of an accident or other emergency.

Training

46(1) An employer must ensure that a worker assigned duties related to confined space entry is trained by a competent person in:

- (a) recognizing hazards associated with working in confined spaces, and
- (b) performing the worker's duties in a safe and health manner.

46(2) An employer must keep records of the training given under subsection (1).

46(3) An employer must ensure that competence in the following is represented in the workers responding to a confined space emergency:

- (a) first aid;
- (b) the use of appropriate emergency response equipment;
- (c) procedures appropriate to the confined space.

Entry permit system

47(1) A person must not enter a confined space at a work site without a valid entry permit.

47(2) An employer must establish an entry permit system for a confined space that

- (a) lists the name of each worker who enters the confined space and the reason for their entry,
- (b) gives the location of the confined space,
- (c) specifies the time during which an entry permit is valid,
- (d) takes into account the work being done in the confined space, and
- (e) takes into account the code of practice requirements for entering, being in and leaving a confined space.

47(3) An employer must ensure that, before a worker enters a confined space, an entry permit is properly completed, signed by a competent person and a copy kept readily available.

47(4) Based on a review of similar confined spaces, an employer may issue an entry permit that can be used for a number of similar confined spaces.

Safety and protection - generally

48(1) An employer must ensure that

- (a) if a lifeline is required in a confined space, it is used in a manner that does not create an additional hazard,
- (b) the safety and personal protective equipment required under this Code is available to workers entering a confined space,
- (c) a worker who enters, occupies or leaves a confined space uses the safety and personal protective equipment,
- (d) the personal protective equipment and emergency equipment required under this Code is available to workers undertaking rescue operations in a confined space,

(e) equipment appropriate to the confined space, including personal protective equipment, is available to perform a timely rescue, and

(f) a communication system is established that is readily available to workers in a confined space and is appropriate to the hazards.

48(2) An employer must ensure that all personal protective equipment and emergency equipment required for use in a confined space is inspected by a competent person before workers enter the confined space to ensure the equipment is in good working order.

48(3) An employer must ensure that written records of the inspections required by subsection (2) are retained.

Protection – hazardous substances and energy

49(1) An employer must ensure that workers within a confined space are protected against the release of hazardous substances or energy that could harm them.

49(2) An employer must ensure that a worker does not enter a confined space unless adequate precautions are in place to protect a worker from drowning, engulfment or entrapment.

Unauthorized entry

50 An employer must ensure that persons who are not authorized by the employer to enter a confined space are prevented from entering.

51 An employer must ensure that workers in a confined space are protected from hazards created by traffic in the vicinity of the confined space.

Testing the atmosphere

52(1) If the hazard assessment identifies a potential atmospheric hazard and a worker is required or authorized by an employer to enter the confined space, the employer must ensure that a competent worker performs a pre-entry atmospheric test of the confined space to

(a) verify that the oxygen content is between 19.5 percent and 23.0 percent by volume, and

(b) identify the amount of toxic, flammable or explosive substance that may be present.

52(2) The employer must ensure that the testing required by subsection (1) is performed using calibrated test instruments appropriate for the atmosphere being tested and the instruments are used in accordance with the manufacturer's specifications.

52(3) The employer must ensure that as often as necessary after the first time a worker enters the confined space, a competent worker

- (a) performs the tests specified in subsection (1), and
- (b) identifies and records any additional hazards.

52(3.1) The employer must ensure that if there is a potential for the atmosphere to change unpredictably after a worker enters the confined space, the atmosphere is continuously monitored in accordance with subsection (2).

52(4) If tests identify additional hazards, the employer must deal with the identified hazards in accordance with this Code.

52(5) The employer must ensure that the procedures and practices put in place under subsection (4) are included in the code of practice.

52(6) The employer must ensure that the results of tests required by this section are recorded.

Ventilation and purging

53(1) If the atmospheric testing under section 52 identifies that a hazardous atmosphere exists or is likely to exist in a confined space, an employer must ensure that the confined space is ventilated, purged or both before a worker enters the confined space.

53(2) If ventilating or purging a confined space is impractical or ineffective in eliminating a hazardous atmosphere, the employer must ensure that a worker who enters the confined space uses personal protective equipment appropriate for the conditions within the confined space.

53(3) If mechanical ventilation is needed to maintain a safe atmosphere in a confined space during the work process, an employer must ensure it is provided and operated as needed.

53(4) If mechanical ventilation is required to maintain a safe atmosphere in the confined space, the employer must ensure that

- (a) the ventilation system incorporates a method of alerting workers to a failure of the system so that workers have sufficient time to safely leave the confined space, and
- (b) all workers within the confined space have received training in the evacuation procedures to be used in the event of a ventilation system failure.

53(5) All workers must evacuate a confined space or use an alternative means of protection if a ventilation system fails.

Inerting

54(1) An employer must ensure that a confined space is inerted if it is not reasonably practicable to eliminate an explosive or flammable atmosphere within the confined space through another means.

54(2) If a confined space is inerted, an employer must ensure that

- (a) every worker entering the confined space is equipped with supplied-air respiratory protection equipment that complies with Part 18,
- (b) all ignition sources are controlled, and
- (c) the atmosphere within the confined space stays inerted while workers are inside.

Emergency response

55(1) An employer must ensure that a worker does not enter or remain in a confined space unless an effective rescue can be carried out.

55(2) A worker must not enter or stay in a confined space unless an effective rescue can be carried out.

55(3) An employer must ensure that the emergency response plan includes the emergency procedures to be followed if there is an accident or other emergency, including the procedures in place to evacuate the confined space immediately

- (a) when an alarm is activated,
- (b) if the concentration of oxygen inside the confined space drops below 19.5 percent by volume or exceeds 23.0 percent by volume, or
- (c) if there is a significant change in the amount of hazardous substances inside the confined space.

Tending worker

56(1) For every confined space entry, an employer must designate a competent worker to be in communication with a worker in the confined space.

56(2) An employer must ensure that the designated worker under subsection (1) has a suitable system for summoning assistance.

56(3) An employer must ensure that a competent worker trained in the evacuation procedures in the emergency response plan is present outside a confined space, at or near the entrance, if

- (a) the oxygen content of the atmosphere inside the confined space is less than 19.5 percent by volume,

- (b) the oxygen content of the atmosphere inside the confined space is greater than 23.0 percent by volume,
- (c) the concentration of a substance listed in Schedule 1, Table 2 inside the confined space is greater than 50 percent of its occupational exposure limit, or
- (d) a hazard other than one listed in clauses (a), (b) or (c) is identified by the hazard assessment and the hazard cannot be eliminated or effectively controlled.

56(4) An employer must ensure that the tending worker under subsection (3)

- (a) keeps track at all times of the number of workers inside the confined space,
- (b) is in constant communication with the workers inside the confined space, and
- (c) has a suitable system for summoning assistance.

56(5) A tending worker must not leave the area until all workers have left the confined space, or another tending worker is in place.

Entry and exit

57 An employer must ensure that a safe means of entry and exit is available to all workers required to work in a confined space, and rescue personnel attending to the workers.

Retaining records

58 An employer must ensure that all records respecting entry and work in a confined space, including entry permits and testing under this Part, are retained for not less than

- (a) 1 year if no incident or unplanned event occurred during the entry, or
- (b) 2 years if an incident or unplanned event occurred during the entry.

Part 10 Fire and Explosion Hazards

General Protection and Prevention

Prohibitions

162(1) A person must not enter or work at a work area if more than 20 percent of the lower explosive limit of a flammable or explosive substance is present in the atmosphere.

162(2) Subsection (1) does not apply to a competent, properly equipped worker who is responding in an emergency.

162(3) A person must not smoke in a work area where a flammable substance is stored, handled, processed or used.

162(3.1) A person must not use an open flame, except in accordance with section 169, in a work area where a flammable substance is stored, handled, processed or used.

162(4) A person must not mix, clean or use a flammable or combustible liquid at a temperature at or above its flash point in an open vessel if a potential source of ignition is in the immediate vicinity of the activity.

162(5) A person must not use a flammable or combustible liquid at a temperature above its flash point in a washing or cleaning operation, unless the washing or cleaning equipment is specifically designed and manufactured for the use of the liquid.

162(6) A person must not store contaminated rags used to clean or wipe up flammable substances other than in a covered container that has a label that clearly indicates it is to be used for the storage of contaminated rags.

Contaminated clothing and skin

164(1) If a worker's clothing is contaminated with a flammable or combustible liquid, the worker must

- (a) avoid any activity where a spark or open flame may be created or exists,
- (b) remove the clothing at the earliest possible time in a manner consistent with clause (a), and
- (c) ensure that the clothing is decontaminated before it is used again.

164(2) If a worker's skin is contaminated with a flammable or combustible liquid, the worker must wash the skin at the earliest possible time.

Protective procedures and precautions in hazardous locations

165(3) An employer must ensure that in a hazardous location,

- (a) equipment used will not ignite a flammable substance, and
- (b) static electricity is controlled,
 - (i) in the case of conductive containers for flammable or combustible liquids while the contents are being transferred, by electrically bonding the containers to one another and electrically grounding them, and
 - (ii) in other cases, by some other effective means.

165(4) An employer must ensure that, if a work area is determined to be a hazardous location, the boundaries of the hazardous location are

- (a) clearly identified to warn workers of the nature of the hazards associated with the presence of the flammable substance in that work area, or
- (b) fenced off to prevent workers or equipment entering the area without authorization.

165(5) If reasonably practicable, an employer must ensure that procedures and precautionary measures are developed for a hazardous location that will prevent the inadvertent release of

- (a) a flammable substance, or
- (b) oxygen gas if it can contact a flammable substance.

165(6) Despite subsection (6), if it is not reasonably practicable to develop procedures and precautionary measures that will prevent release, an employer must develop procedures and precautionary measures that will prevent an explosive atmosphere igniting in a hazardous location.