

Detection and Control of Flammable Substances

PARTICIPANT MANUAL
VERSION 22.1

**E N E R G Y
S A F E T Y
C A N A D A**

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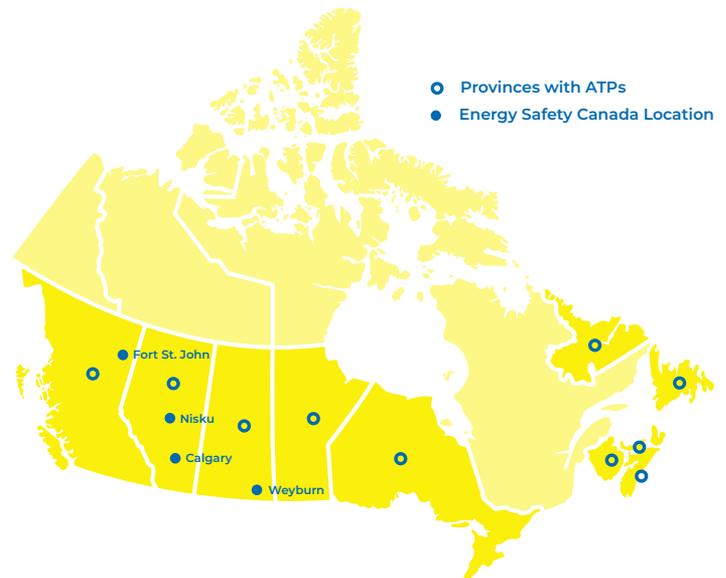


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PREFACE

AIM

The aim of this training is to prevent injuries, fatalities and property damage due to exposure to flammable substances in the Canadian Petroleum Industry through better informed workers.

GOALS

The goals for this training are as follows:

- » To provide petroleum industry workers with a basic level of understanding of the characteristics of flammable liquids, gases and vapours.
- » To provide petroleum industry workers with a basic knowledge and skill in order to protect themselves and others from exposure to flammable substances.

SCOPE OF COURSE

This detection and control of flammable substances course is designed to familiarize petroleum industry workers with the hazards of flammable substances, precautionary measures for working in environments where flammable substances are present, and proper detection practices using catalytic detection instruments.

The information contained in this course is provided from a safety perspective only. It does not address occupational health or hygiene monitoring practices. Such monitoring practices require additional training with other types of instrumentation to determine very low level concentrations of substances including gases and vapours with other toxic effects, such as hydrogen sulphide, benzene, toluene and xylene.

Training courses, such as H₂S Alive®, provides additional information to complement the information contained in this course. Occupational Health and Safety legislation provides specific requirements when working in potentially toxic or explosive environments.

DIRECTION TO EMPLOYERS

The Detection and Control of Flammable Substances training provides students with a description of the characteristics of flammable substances (gases/ vapours) along with the identification of associated hazards and suggested control methods. The training also provides an introduction to the use of a catalytic combustible gas monitor in terms of conducting a function test and calibration strategies.

To complete the training, additional site specific training should be conducted in order to ensure that the individual has the required skills to competently carry out his assigned duties in the detection and control of flammable substances. A checklist is provided on the next page. This checklist serves as a guide to employers and may not address all of the necessary site specific training required for a particular worksite. Employers are encouraged to modify this checklist.

DETECTION AND CONTROL OF FLAMMABLE SUBSTANCES WORKSITE TRAINING – CHECK LIST

Workers Name: _____

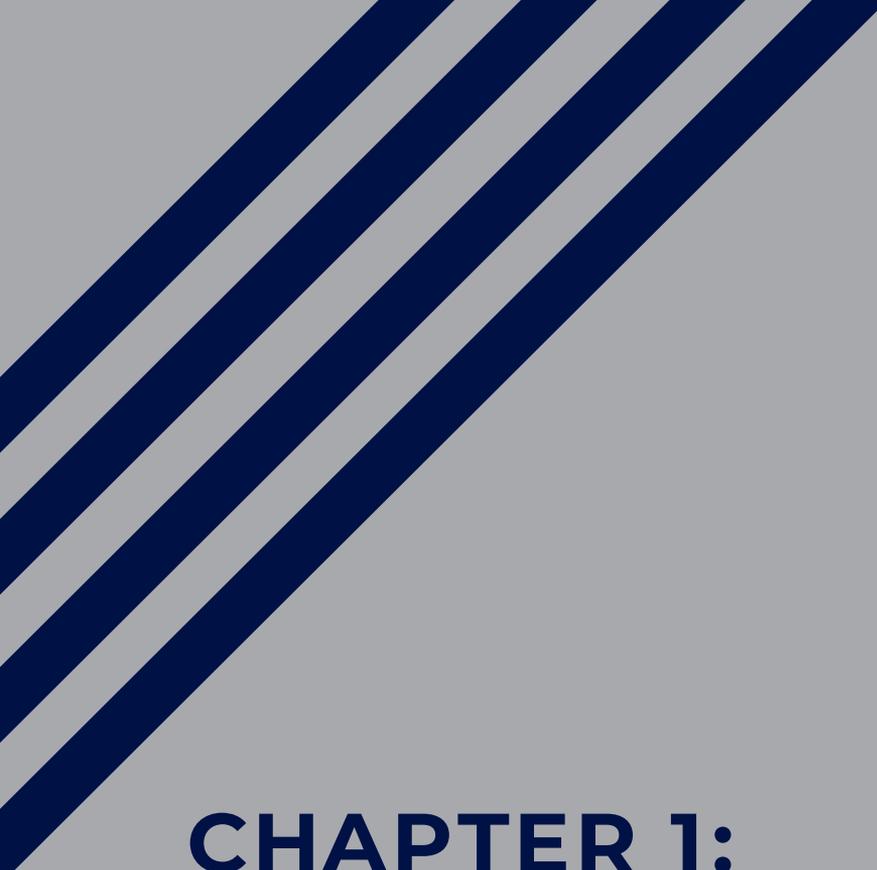
Start Date: _____ Completion Date: _____

(YYYY / MM / DD)

ITEM	* COMPLETION YES, NO OR NA (NOT APPLICABLE)	DATE	SUPERVISOR SIGNATURE	COMMENTS
Locate all on-site flammable substances				
Identify types of flammable substances on-site				
Identify work related tasks associated with exposure to flammable substances				
Conduct function test and evaluate results of all monitors used by worker				
Identify above monitor(s) calibration requirements				
Identify worksite specific safe exposure levels for workers				
Implement operation specific control measures (including SCBA/SABA if required)				

*** Provide explanation in comment column on all NO or NA items.**

Supervisor's Signature: _____



CHAPTER 1:

Introduction to Flammable Substances



OUTCOME

Describe the properties of flammable substances and general precautionary measures needed when working with them.



OBJECTIVES

1. Describe each of the four states of flammable substances.
2. Identify potential locations of flammable substances within the petroleum industry.
3. Define and interpret LEL, UEL and explosive range.
4. Describe the properties of flammable gases/ vapours including associate hazards and precautionary measures.

INTRODUCTION

There are a number of hazards located at oil and gas industry worksites with the potential to cause serious worker injury, health risks, and/or property damage. In particular, complex mixtures of different types of products found as solids, liquids, gases and/or vapours can be flammable, toxic, corrosive or radioactive. To ensure that worker and site safety can be managed, a comprehensive Hazard Assessment and Control Program is required before work starts.

This training program addresses some of the potential hazardous locations on oil and gas work

An Important Note on Training:

Additional training programs and specific Health and Safety (Industrial Hygiene) Programs are necessary to develop a more comprehensive understanding of the hazards and best safety practices in the oil and gas sector. More information on substances like hydrogen sulfide, benzene, toluene, ethyl benzene, xylene (BTEX), and Naturally Occurring Radioactive Materials (NORM) can be obtained from the Canadian Association of Petroleum Producers (CAPP) and/ or Energy Safety Canada.

FLAMMABLE SUBSTANCES

Flammable Substances are divided into four physical states:

- » Solids
- » Liquids
- » Vapours
- » Gases

Solids

Flammable solids are any materials in the solid phase of matter that can readily undergo combustion in the presence of a source of ignition. Many flammable solids may react violently or explosively on contact with water and may also be ignited with friction, heat, sparks or flame. Some of these materials will burn with intense heat. Dusts or fumes may form explosive mixtures in air. Containers may explode when heated. Materials may re-ignite after fire is extinguished. Fires may produce irritating, corrosive and/or toxic gases. Some of these materials may also be pyrophoric – spontaneously reacting with the oxygen in air to ignite.

For metallic flammable solids (e.g., phosphorus, sodium, lithium, magnesium) do not use water, foam or carbon dioxide as a fire suppressant. Dousing metallic fires with water may generate hydrogen gas, an extremely dangerous explosion hazard, particularly if fire is in a confined environment. Additionally, fires involving flammable metals (e.g., lithium, sodium, potassium) or flammable metal compounds (e.g., butyllithium, diethylzinc) can be fueled by using water or carbon dioxide fire extinguishers. You must have a Class D extinguisher on hand if you are using these materials. Extinguishers for Class D fires are labeled with a list detailing the metals that match the unit's extinguishing agent. Flammable solids may also include carbon-based substances such as asphaltene (tar), iron sulphide, coal, charcoal, paraffin and greases found throughout the oil and gas industry. The best precautionary measure for these carbon-based substances is to keep the material wet.

Liquids

Generally, a flammable liquid is a liquid that can catch fire. Flammable liquids may include carbon based substances such as crude, refined diesels and gasoline, petroleum solvents and other distillates found throughout the oil and gas industry. Flammable liquids give off vapours that can easily be ignited at normal working temperatures.

To control the potential hazards posed by handling flammable and combustible liquids, several properties of these materials should be understood. Information on the properties of a specific liquid can be found in that liquid's **Material Safety Data Sheet (MSDS)**, **(SDS) Safety Data Sheets** or other reference material.

It is the liquid's vapor rather than the liquid itself that ignites when mixed with air in the presence of an ignition source. Flammable and combustible liquids vaporize and form flammable mixtures with air when in open containers, when leaks occur, or when heated. **Volatility** is the tendency or ability of a liquid to vaporize. **Vapor pressure** is a measure of a liquid's volatility. A high vapor pressure usually is an indication of a volatile liquid, or one that readily vaporizes. The **boiling point** is the temperature at which the vapor pressure equals atmospheric pressure, such that the pressure of the atmosphere can no longer hold the liquid in a liquid state and bubbles begin to form. In general, a low boiling point indicates a high vapor pressure and, possibly, an increased fire hazard.

An important characteristic of any flammable or combustible liquid is its flashpoint. **Flashpoint** is the minimum temperature at which the vapor concentration near the surface of the liquid is high enough to form an ignitable mixture. Under Workplace Hazardous Materials Information System (WHMIS), a flammable liquid has a flashpoint under 37.8°C. Any liquid with a flashpoint between 37.8°C and 93.3°C is considered combustible. In general, the relative hazard of a flammable liquid increases as the flashpoint decreases.

NOTE: Solids and liquids do not burn in their original physical state! It is the vapour from a solid or liquid that burns. This training program deals with the detection of flammable gases and vapours using a combustible gas monitor.

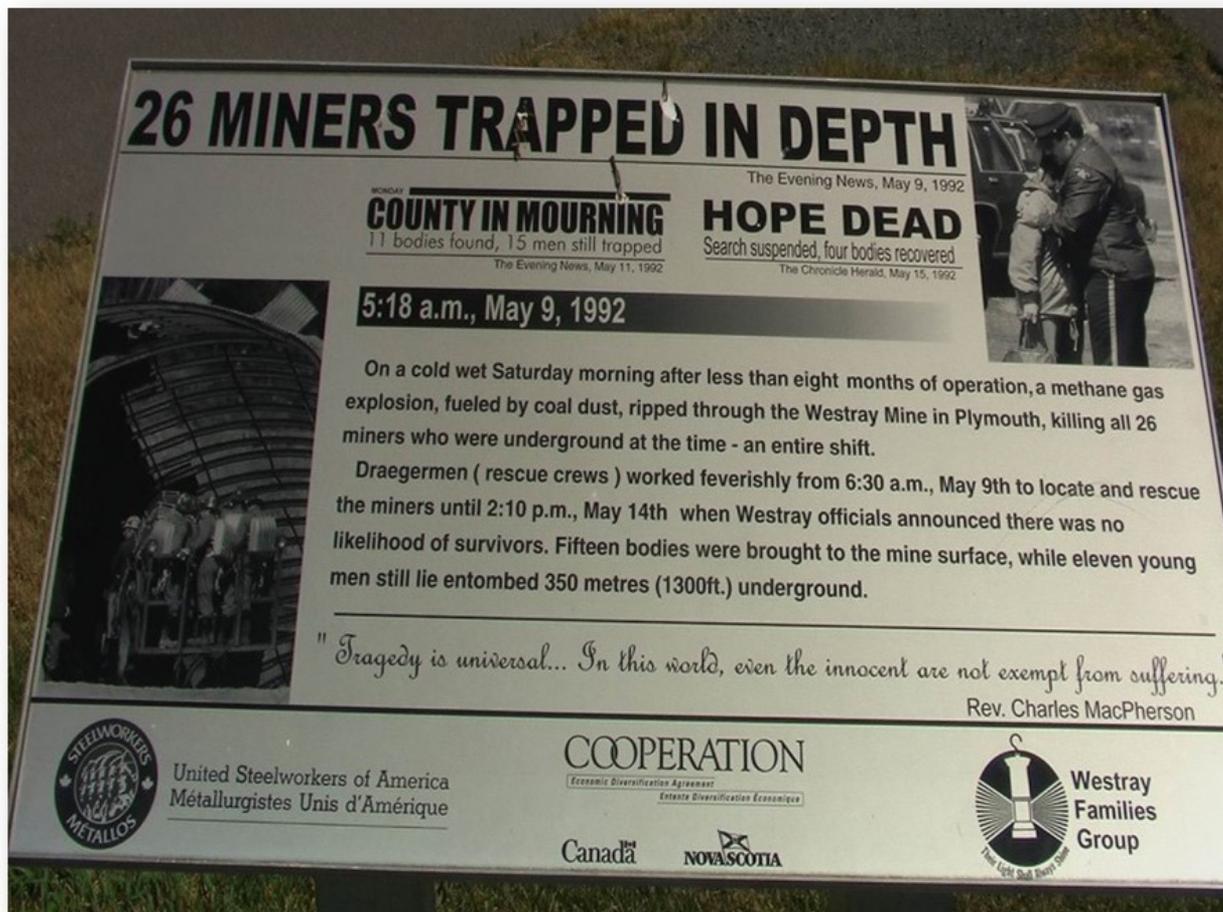
Vapours

Flammable vapours are generated due to the evaporation of a solid or liquid. Vapours can re-solidify or re-liquefy depending on the temperature and pressure. All liquids and solids will vaporize. The hazardous ones readily vaporize at normal working temperatures (e.g., gasoline). "Safer" products only vapourize at higher temperatures (e.g., diesel fuel). Generated vapours will spread out, mix with air and other vapours, and fill all available space. Depending upon the density (heavier or lighter than air) of the vapour, and the temperature of release, the vapour may settle or rise depending on the ambient conditions.

Gases

Some of the flammable gases found in the oil and gas industry include the four hydrocarbon gases (Methane CH_4 ; Ethane C_2H_6 ; Propane C_3H_8 ; Butane C_4H_{10}) and contaminant gases such as hydrogen sulfide. These gases are difficult for the human senses to detect because they are colourless, tasteless, and with the exception of H_2S , they are odourless. However, in some circumstances, a chemical with a strong unpleasant odour may be added to hydrocarbon gases so people can detect their presence; this process is known in the industry as stenching (odorizing). Even when stenching occurs, our human senses cannot be relied upon to provide reliable information on the flammability of a substance. **Therefore, the only reliable and competent way of detection is a Combustible Gas Monitor used by a trained and knowledgeable worker.** As is the case with vapours, all gases will expand and contract, mix with each other and fill all available space. Depending on the density, gases can be lighter or heavier than air and may settle or rise depending on ambient conditions.

Figure 1-1 Westray Mine



On May 9, 1992, methane gas and subsequent coal dust explosions killed 26 miners in the Westray Mine in Plymouth, Nova Scotia.

Assessment and Detection of Flammable Hazards

In the oil and gas industry, there are several ways to assess and detect potential flammable hazards on a worksite, the more common approach includes:

- » Training in and knowledge of hazards and work procedures
- » Review of the MSDS/SDS
- » Use of detection devices

Using the MSDS/SDS for example, an individual is able to identify and assess various safety threats present at the worksite. When properly used, the MSDS/SDS is a formal document containing important information about the characteristics and actual threats posed by various substances present in the worksite. The MSDS/SDS usually includes chemical identity, hazardous ingredients, physical or chemical properties, fire and explosion data, reactivity data, health hazards data, exposure limits data, precautions for safe storage and handling, need for protective gear, and spill control, cleanup, and disposal procedures.

Location of Flammable Substances

Flammable hydrocarbons and other gases/ vapours may be found in any of the following locations in the oil and gas industry:

- » Floors on drilling and service rigs
- » Drilling rig sub-structures
- » Blow Out Prevention Systems
- » The head space of produced water or liquid hydrocarbon tanks
- » High pressure storage tanks or bullets
- » Pipelines
- » Meter and process buildings as a result of leaks or instrument bleed lines
- » Pig traps
- » Storage tank and process vessels recently emptied of hydrocarbon liquids
- » Vent lines
- » Mud tanks and shale shakers
- » Shops repairing field equipment
- » Tank Trucks



Figure 1-2 Pre-entry testing

Depending upon the substance, concentration, and the type of work being undertaken, a fire hazard may be present.

NOTE: Toxic gas, oxygen deficiency or other hazards may also be present in these locations.

Explosive/Flammable Range

All fuels are flammable in the presence of the right amount of oxygen and a suitable ignition source. Sources of ignition found on a typical oil and gas worksite include: chemical reaction (e.g., iron sulphide), open flame, sparks from electricity or friction, heat from engine manifolds and exhaust systems, and static electricity from clothing and fluid transfer.

Flammable substances will burn if mixed with the correct amount of air (oxygen) and with a suitable ignition source (energy) available to ignite the mixture producing the chemical reaction (fire). The amount of fuel required to burn is expressed in terms of the substance's Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL).

NOTE: The terms “Flammable”, “Explosive” and “Combustible” have the same meaning in the context of this manual.

Lower Explosive Limit (LEL)

Refers to the minimum amount of fuel that must be present in the air for a substance to burn. If there is too little fuel, the mixture is considered “lean” and will not burn.

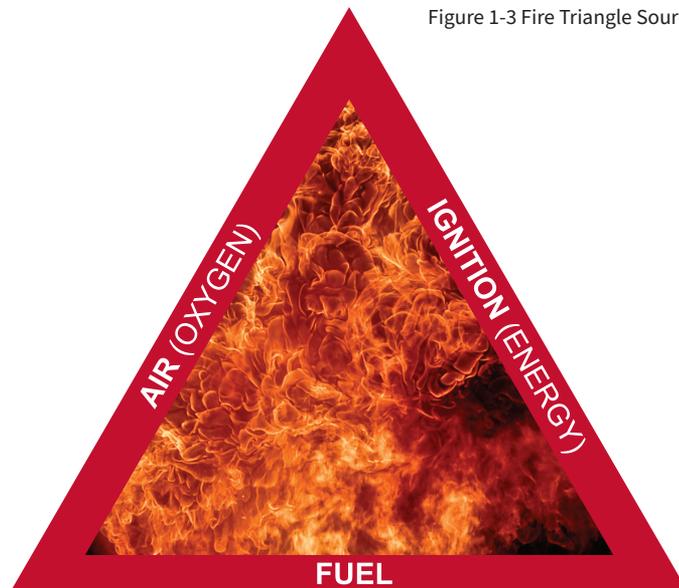
Upper Explosive Limit (UEL)

Refers to the maximum amount of fuel that must be present in the air for a substance to burn. If there is too much fuel, the mixture is considered “rich” and will not burn.

The range between the LEL and UEL is called the **Explosive or Flammable Range**. The values are expressed in percent (%) fuel by volume in air.

Table 1-1 provides the LEL and UEL for different substances. The wider the explosive range, the more difficult it is to manage the potential for a fire. This is a critical concern when attempting to purge a tank or vessel.

Figure 1-3 Fire Triangle Sources



Lower Explosive Limit (LEL)
 The minimum concentration of fuel in the air required to create an explosion if ignited.

Why this matters?
 Ensuring fuel/fuel mixtures in the air does not rise above LEL is a key method to prevent fires and explosions—gas monitoring with LEL-based warnings are safety critical.

Upper Explosive Limit (UEL)
 The point at which fuel concentration is so high, there is not enough oxygen to create an explosion.

Why this matters?
 In enclosed systems, fuel/fuel mixtures will not ignite. However, if oxygen is introduced to the system, eventually a mixture below the UEL will occur creating the potential for an explosion.

1. Explosive Limits Vary
 The explosive limits (LEL/UEL) can vary for different fuels and mixtures.

Why this matters?
 The wider the explosive range, the greater the probability of encountering the right conditions for a fire or explosion.

2. Chance of explosion below LEL and above UEL
 A number of factors including the exact properties of the fuel mixture, nature of ignition sources or other critical risk factors can make it possible for explosions to occur below the LEL and above the UEL.

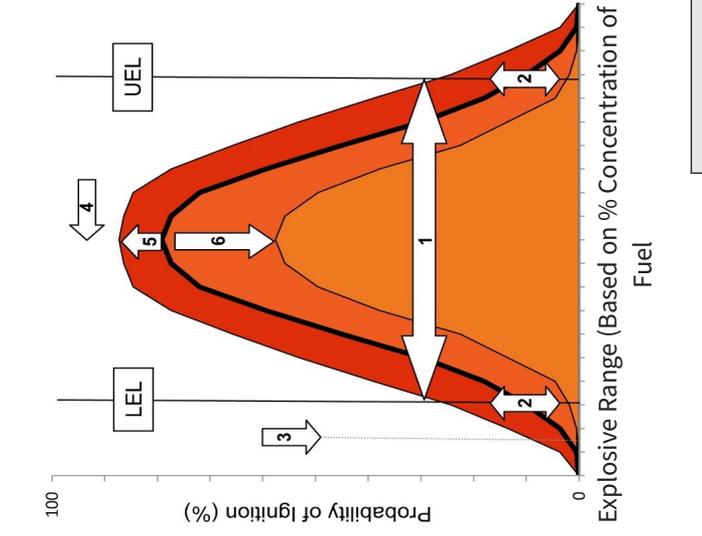
Why this matters?
 Just because monitors are reading fuel levels below the estimated LEL, ongoing or additional controls and precautions may still be required.

4. Chance of explosion is never 100%
 The gap here illustrates that even under perfect conditions, a fire or explosion may not occur.

Why this matters?
 You may create ideal conditions for a fire or explosion and not realize it—and not have an incident. This can lead to the false conclusion that since you've never had a fire or explosion, the operation or operating conditions must be safe.

5. Critical risk factors increase probability
 The red band illustrates how critical risk factors increase the probability for a fire and explosion over the full range of the explosive envelope.

Why this matters?
 If you are familiar with a particular fuel or type of operation, you may underestimate hazards if you fail to consider new critical risk factors introduced.



3. Half (50%) LEL
 This is a key margin for error when working with fuels or fuel mixtures.

Why this matters?
 Typically 10% LEL triggers alarms while 20% LEL reading should trigger engaging additional controls. In some jurisdictions, 20% LEL is a regulated exposure limit. In most operations, a reading of 50% of LEL will be treated as critical since a flash fire will burn out to approximately the 50% LEL level.

6. Lower energy ignition sources reduce the probability of ignition
This lower line illustrates how reducing the energy of ignition sources can reduce the probability of ignition.

Why this matters?
 If you cannot eliminate, but you can control the energy output of an ignition source, you can reduce the probability of an explosion (e.g. low voltage radios, anti-static footwear, grounding straps) to consider new critical risk factors introduced.

*Illustration presumes oxygen concentration above the minimum oxygen concentration and does not represent a particular substance.

Figure 1-4 Factors Affecting Ignitability of Flammable Materials

Properties of Flammable Substances

The flammable substances found at an oil and gas industry worksite vary in composition and physical characteristics. The only common link is that all of the carbon-based substances will burn in the presence of oxygen (air) and an ignition source (energy). Based on this fact, we can determine the flammable hazard associated with gas or vapour by correctly using a combustible gas monitor.

The properties of the gases and liquids identified with a single asterisk (*) in Table 1-1 are from Dangerous Properties of Industrial Materials; N. Irving SAX, 6th Edition. The LEL and UEL values taken from SAX are actual values. LEL and UEL values used later in this manual are approximate values used for illustrative purposes only.

Table 1-1 Properties of Flammable Substances

	FLAMMABLE SUBSTANCE	SPECIFIC GRAVITY**	VAPOUR DENSITY***	LOWER EXPLOSIVE LIMITS	UPPER EXPLOSIVE LIMITS
GASES	Air	-	1	-	-
	Butane*	-	2	1.9%	8.5%
	Carbon Monoxide	-	0.97	12.5%	74%
	Ethane*	-	1.04	3%	12.5%
	Hydrogen*	-	0.069	4.1%	74.2%
	Hydrogen Sulfide*	-	1.189	4.0%	46%
	Methane*	-	0.6	5.3%	15%
	n-Pentane	-	2.48	1.5%	7.8%
	Propane*	-	1.56	2.3%	9.5%
LIQUIDS	Benzene*	0.879	2.77	1.4%	8%
	Crude Oil	0.7 – 1.1	3.0 – 5.0	1%	7%
	Cutter Oil	0.839	6.1	1.1%	6.0%
	Diesel	0.865	5	1%	6%
	Envirovert (Drilling Fluid)	.97 – 1.20	4	0.7%	6%
	Gasoline (50-100 Octane)*	< 1.0	3.0 – 4.0	1.3%	6%
	Heptane	0.684	3.45	1.05%	6.7%
	Methanol*	0.79	1.11	6%	36.5%
	n-Hexane*	0.66	2.97	1.2%	7.5%
	Toluene*	0.866	3.14	1.27%	7.0%
	Varsol*	0.64 – 0.66	2.5	1.1%	5.9%
	Xylene*	0.86	3.7	1%	7%

ALWAYS refer to the MSDS/SDS sheet for specific information on all flammable substances (WHMIS)

*From Dangerous Properties of Industrial Materials; N. Irving SAX, 6th Edition.

**Specific Gravity: Comparison of the weight of a liquid/solid to the weight of water. Values less than one (1) indicate a substance that is lighter than water.

***Vapour Density: Comparison of the weight of a gas/vapour to the weight of air. Values less than one (1) indicate a substance that is lighter than air.

NOTE: When the % LEL level rises, work should stop and further evaluation should be conducted. CAPP has recommended a 10% LEL standard in order to provide a high degree of safety in the industry.

Regulatory authorities throughout Canada have differing legislative requirements pertaining to worker exposure to combustible gases/vapours and the use of respiratory protective equipment. Therefore, to obtain more precise information on specific jurisdictional legislative requirements, it is suggested that you consult the appropriate territorial, provincial, and/or federal agency responsible for worker safety.

Density of Gases/Vapours

Table 1-1 identifies gases and vapours that are lighter and/or heavier than air (vapour densities). These densities are based on standard temperature and pressure and as a result may vary at the worksite.

For example:

- » A gas released under pressure will go in the direction of the pressure release
- » A gas or vapour release that is warmer than the surrounding air may rise regardless of the vapour density
- » A gas or vapour release that is colder than the surrounding air will drop regardless of the vapour density
- » Heating the side of a tank (e.g., sun) will cause the air/gases/vapours inside the tank to create a circular flow regardless of the vapour density
- » Methane mixed with heavier production gases/vapours may act like the heavier gases/vapours and travel to low spots or carry smaller amounts of heavier gases/vapours up
- » Gases dissolved in a liquid and vapours evaporating from that liquid will have the highest concentration immediately above the liquid level
- » Gases and liquids may collect in pipe bends, behind tank baffles or barriers and in hoses

Gas/Vapour Stratification

In a closed tank or vessel where there is limited disturbance to the gases and vapours, the gases and vapours will tend to stratify (form layers). The heavier gases/vapours will drop and the lighter gases will rise.

Remember that even though the gasses or vapours stratify, opening the hatch or man-way may expose you to potentially harmful or fatal concentrations of gas/vapour. Proper operating procedures should always be followed for purging and cleaning tanks.

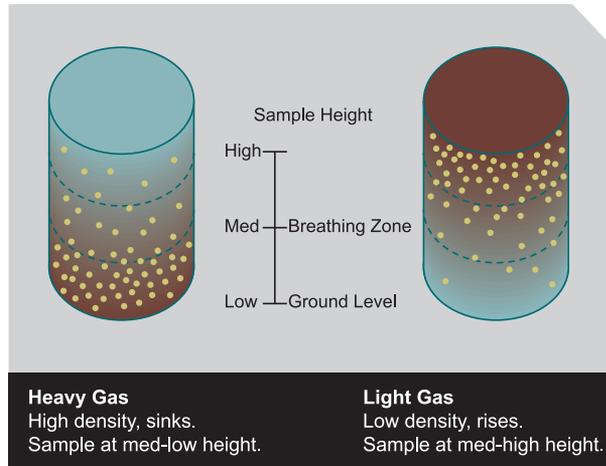


Figure 1-5 Heavy/lighter gas showing varied densities

DISCUSSION

- » What would happen to the concentrations if you opened up the hatch at the top or bottom of either of these tanks?

What would the effect be on you?

Diffusion Gas/Vapour

Gases will diffuse (spread) from an area of high concentration to an area of low concentration.

NOTE: You must check for flammable substances in sumps, ditches, drains, open roof areas as well as enclosed areas. Monitor for flammable gases/ vapours in high areas, low areas, hidden areas, and workers' breathing zones. A monitoring plan is required.

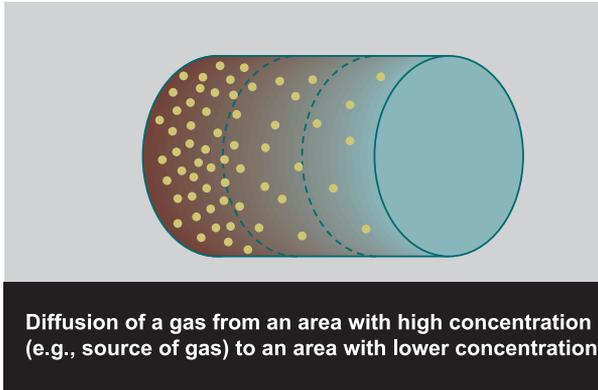


Figure 1-6 Gas/Vapor Diffusion

DISCUSSION

- » What would happen to the concentrations if you opened up the hatch at the left or right side of this tank?

What would the effect be on you?

General Precautionary Measures

When working with flammable substances, the following precautionary measures should be followed at all times:

- » Review your work procedures. Check to see if you are using spark or heat producing tools or equipment. If you are transferring flammable materials ensure correct electrical bonding and grounding to prevent static spark.
- » Observe the wind direction and other work activities on the site to determine if you or others might be exposed to hazardous conditions.

- » Use mechanical ventilation to reduce the concentration of combustible gases and vapours in the work area.
- » Do not attempt to put out a hydrocarbon fire unless you are trained to do so and know the composition of the burning fuel. It is often safer to let the gas burn than to let the unburned gas escape where it may explode later or create a toxic gas exposure to workers and the public.
- » Wear fire retardant clothing while you are working. This is a requirement to minimize burn injuries.
- » Learn how, where and when to use the combustible gas monitor correctly and safely.

Health Hazards

In addition to the fire and explosion threats associated with flammable substances, many of the substances have serious health hazards that need to be addressed to ensure a safe worksite. The following are some major health hazards:

- » Many gases and vapours can act as an asphyxiant gas, which reduces or displaces the normal oxygen concentration in breathing air (reducing the oxygen concentration below 19.5% by volume).
- » Hydrocarbon gases (e.g., methane, ethane, butane and propane) have been linked to a narcotic response characterized by disorientation, headaches, inability to make decisions, delayed responses, memory loss, dizziness, and an unsteady gait. The recommendation from CAPP is to protect workers with a Self-Contained Breathing Apparatus (SCBA) or Supplied Air Breathing Apparatus (SABA) if they are exposed to combustible gas/vapour concentrations above 10% LEL.
- » Hydrogen sulphide and carbon monoxide have been shown to have toxic effects on workers when exposed to gas concentrations above their respective Occupational Exposure Limits (OELs) which may be well below the 10% LEL limit for that gas.

Flammable Liquids and Phase Changes

In order to facilitate storage and transport, many hydrocarbon gases are pressurized and cooled to a point where they change into a liquid phase. Under these conditions, a rupture of the storage or transport cylinder can release the pressure. As the pressure drops, the contents may change state from liquid to gas, increasing the volume of the contents. Even a small spill can generate large amounts of flammable gas. For example, propane will expand 272 times its volume during a phase change from liquid to gas.

As it expands, the propane will mix with air until the mixture enters the explosive range. The estimated volumes are:

1 LITRE OF LIQUID PROPANE

= 272 litres @ 100% by volume propane gas

= 2,800 litres @ 9.5% by volume (UEL)

= 12,950 litres @ 2.1% by volume (LEL)

= 129,524 litres @ 10% LEL

Precautionary Measures

Release of hydrocarbon liquids can form large vapour clouds. A vapour cloud may travel long distances before dispersing. The majority of vapours released during expansion or evaporation are heavier than air and will have a tendency to spread to low-lying areas and sewers. A vapour cloud explosion or Boiling Liquid Expanding Vapour Explosion (BLEVE) releases large amounts of energy and is very destructive.

SELF-EVALUATION / REVIEW

The following is a self-evaluation aimed at testing your understanding of the material presented in this chapter. This exercise should take approximately 15 minutes to complete. You should NOT look back on the information in this chapter nor should you look at the answer key provided. You should be able to answer a minimum of 9 of the 11 multiple choice questions correctly. You should review all the questions you have wrong by reading that part of the chapter again and/or discussing the question(s) you had wrong with your instructor prior to moving onto the next chapter.

- 1. What does the Vapour Density of a substance that is less than one (1) mean?**
 - a. Substance is heavier than air
 - b. Substance contains more water than the air around it
 - c. Substance is lighter than air
 - d. Substance contains less water than the air around it

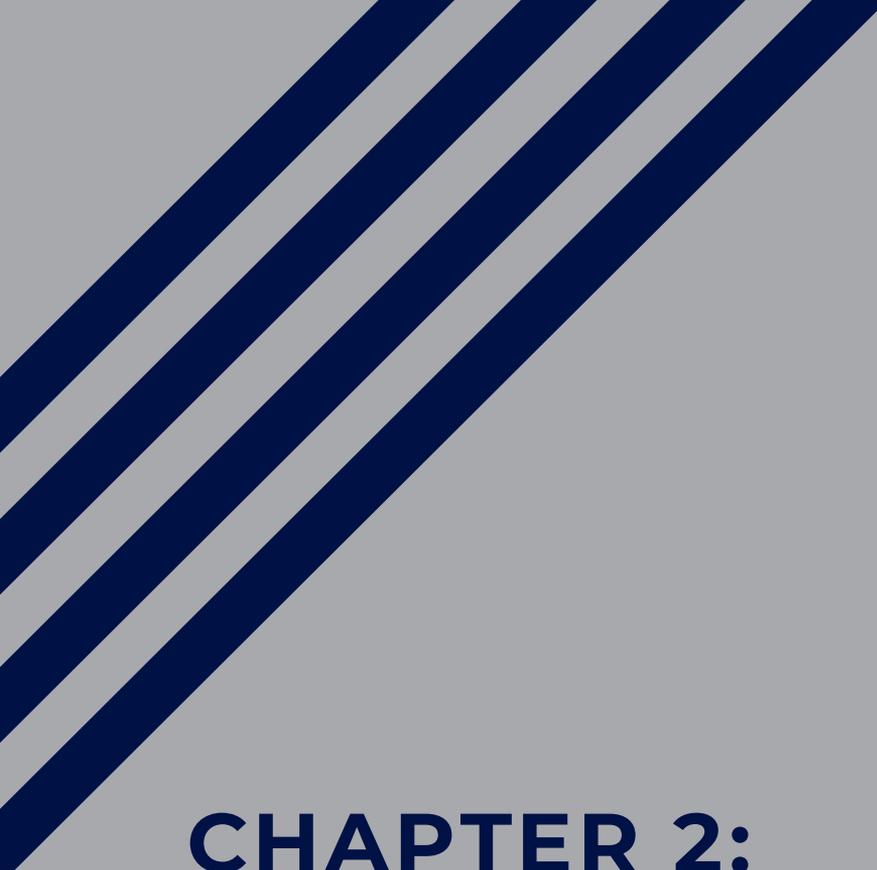
- 2. What does the Specific Gravity of a substance that is more than one (1) mean?**
 - a. Substance is heavier than water
 - b. Substance is lighter than air
 - c. Substance is lighter than water
 - d. Substance contains less water than the air around it

- 3. What do you call the process of adding a chemical to an odourless gas in order to detect its presence through the sense of smell?**

- 4. Which of the following is the most reliable means of detecting flammable gas/vapour?**
 - a. Use of our senses (taste, sight and smell)
 - b. Material Safety Data Sheets
 - c. Use of a combustible gas monitor
 - d. Prior knowledge of the processes in place at

- 5. Based only on flammable substance, at what LEL concentrations should cold work be carried out without SCBA?**
 - a. 100% LEL
 - b. 20% LEL
 - c. 15% LEL
 - d. 5% LEL

- 6. What do we call the range of combustible gas concentrations in air that can explode in the presence of a suitable ignition source?**
 - a. EL range
 - b. UEL range
 - c. Operational range
 - d. Explosive range



CHAPTER 2:

Principles of Flammable Gas/Vapour Detection



OUTCOME

Describe the principles of flammable substance detection and the instrumentation used to maintain a safe work environment



OBJECTIVES

1. Explain the advantages and disadvantages of infrared gas detectors.
2. Explain the advantages and disadvantages of catalytic combustible gas detectors.
3. Explain housing and operational factors that affect catalytic combustible gas monitors.

INTRODUCTION

Industrial processes in the oil and gas sector increasingly involve the use and manufacture of highly dangerous substances, particularly flammable, and toxic gases. Inevitably, occasional escapes of gas occur, which create a potential hazard to employees and people living near industrial operations. Incidents around the world involving asphyxiation, explosions and loss of life, are a constant reminder of this problem.

In most industries, one of the key parts of any safety plan for reducing risks to personnel and property is the use of early-warning devices such as gas detectors. These can help to provide more time in which to take remedial or protective action. They can also be used as part of a total, integrated monitoring and safety system for industrial operations in the oil and gas sector.

This chapter is intended to offer a simple guide to anyone considering the use of such gas detection equipment. It provides an explanation of both the principles involved and the instrumentation needed for satisfactory protection of personnel, property and the environment.

When designing a combustible gas safety monitoring system for oil, gas, petrochemical or other applications, infrared or catalytic gas detector technology is often used. Both sensing technologies have their advantages and disadvantages dependent upon your application's specific requirements. A thorough analysis of your application's unique field environment is needed to ensure optimal performance, safety, reliability and cost-effectiveness.

Infrared Gas Detectors/Monitors

Infrared (IR) gas detection is a well-developed measurement technology. Infrared gas detectors have a reputation for being complicated, cumbersome, and expensive. However, recent technical advancements, including the availability of powerful amplifiers and associated electronic components, have opened a new frontier for infrared gas detection.

The IR detection method is based upon the absorption of infrared radiation at specific wavelengths as it passes through a volume of gas. Typically two infrared light sources and an infrared light detector measure the intensity of two different wavelengths, one at the absorption wavelength and one outside the absorption wavelength. If a gas intervenes between the source and the detector, the level of radiation falling on the detector is reduced.

Gas concentration is determined by comparing the relative values between the two wavelengths. Gases to be detected in the oil and gas field are often corrosive and reactive. With most sensor types, the sensor itself is directly exposed to the gas, often causing the sensor to drift or die prematurely.

The main advantage of IR instruments is that the detector does not directly interact with the gases to be detected. The major functional components of the detector are protected with optical parts. Only the sample cell and related components are directly exposed to the gas sample stream. These components can be treated, making them resistant to corrosion, and are designed such that they are easily removable for maintenance or replacement.

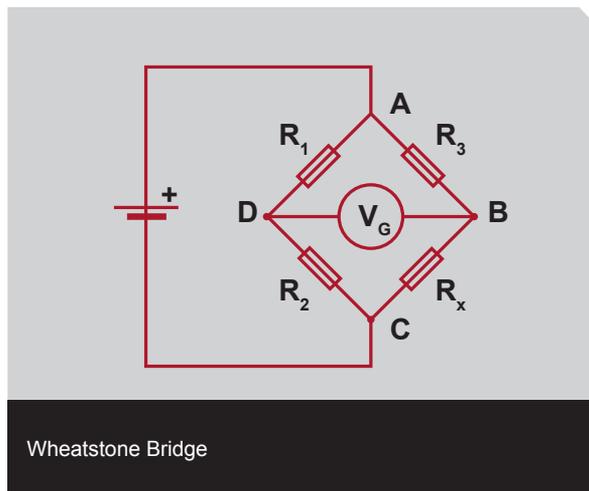
Common gases detected by IR sensors include butane, carbon dioxide, ethane, ethanol, ethylene, ethylene oxide, hexane, methane, methyl bromide, nitrous oxide, pentane, propane, and propylene. Gases not detected by IR detectors include hydrogen, acetylene, and aromatic compounds, like benzene and toluene. Again, in detecting combustible gases in the oil and gas sector, it is important to consider the specific compounds to be monitored as there are some that do not readily lend themselves to detection with a general purpose IR detector. Additional advantages and disadvantages for IR detectors are provided below.

Table 2-1 Major Advantages and Disadvantages of IR Gas Detectors

ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none"> » Can Operate without Oxygen or Enriched Oxygen » Immunity to Contamination and Poisoning » Consumables Outlast Catalytic Detectors – Both source and detector » Less Calibration Required – Compared to catalytic detectors » Can Operate with Continuous Presence of Gas » Reliable in Varying Gas Flow Conditions – For example, even if detector is flooded it will continue to show high readings and the sensor will not be damaged » Detects Levels Higher than 100% LEL – Most detectors only measure from 0-100% of the LEL (e.g., Max reading for methane would be 5% volume of methane or 50,000 ppm) 	<ul style="list-style-type: none"> » Higher Initial Cost – IR detectors are usually more expensive to purchase than catalytic detectors » Higher Parts Costs – IR detectors cost more to repair » Gases are Not Detectable if they do Not Absorb IR Energy – e.g., Hydrogen » High Humidity, Dusty and Corrosive Field Environments are Hard on Detectors – IR detector maintenance costs increase » Temperature Range is Limited – Compared to catalytic detectors IR detectors operate across a smaller temperature range » May Not Perform Well with Multiple Gases Present – Leads to lower confidence in accuracy of readings

Catalytic Combustible Gas Detectors

Catalytic detectors are based upon the principle that when gas oxidizes it produces heat, and the sensor converts the temperature change via a standard Wheatstone Bridge-type circuit to a sensor signal that is proportional to the gas concentration. The sensor components consist of a pair of heating coils (reference and active). The active element is embedded in a catalyst. The reaction takes place on the surface of the catalyst, with combustible gases reacting exothermically with oxygen in the air to raise its temperature. This results in a change of resistance.



There is also a reference element providing an inert reference signal by remaining non-responsive to gas, thereby acting as a stable baseline signal to compensate for environmental changes, which would otherwise affect the sensors temperature.

Catalytic detectors are the most widely used of the two types of combustible gas detectors and therefore the main focus of this chapter. They are available in small personal monitors or “lunch-box” sized portable monitors for simple hydrocarbon gas monitoring or combined with oxygen and toxic gas sensors such as Hydrogen Sulphide (H_2S) and/or Carbon Monoxide (CO) for multi-gas monitoring. Catalytic detectors are also used as fixed monitors that are permanently located in buildings and are typically connected to alarms and process controls. Catalytic detectors rely on two sampling systems. The sampling system is the means by which the air sample is drawn to the combustible gas sensors. An air sample is drawn to the monitor’s combustible gas sensors either by means of a passive or active

sample draw system. In a passive system, the combustible gas sensors are directly exposed to the atmosphere and the sample diffuses to the sensor elements. In an active system, a hand aspirator or motorized sample draw pump and sampling hose are used to draw the sample to the sensors.



Figure 2-1
Passive Gas
Detector



Figure 2-2
Active Gas
Detector



Figure 2-3
IR Gas Detector

NOTE: Sampling hose material must be compatible with the gases being monitored. Leak tests should also be carried out. See the Manufacturer’s manual.

Active monitoring is normally carried out using portable, handheld detectors. The operator carries the instrument around while monitoring. This is usually used for remote sampling.

This may be to:

- » Monitor the general area
- » Monitor the atmosphere within a confined space
- » Check for leaks from likely sources (e.g., drains or flange)

NOTE: Catalytic sensors measure up to 100% LEL. They should not be used for leak checking where 100% by volume gas is encountered. Suggest infrared systems.

Table 2-2 highlights some of the common advantages and disadvantages associated with both passive and active catalytic sampling systems.

Table 2-2 Advantages and Disadvantages of Sampling Systems

SAMPLING SYSTEM	ADVANTAGES	DISADVANTAGES
Passive	<ul style="list-style-type: none"> » No sample loss because sensors directly exposed to environment » Small, portable, one hand operation » Can be converted into active system with attachments 	<ul style="list-style-type: none"> » Base models do not provide for remote sampling » Worker may be exposed to a potentially contaminated environment
Active	<ul style="list-style-type: none"> » Sensors securely mounted in housing » Faster response if sampler hose is short 	<ul style="list-style-type: none"> » Potential sample loss in hose due to leaks, condensation and absorption » Power supply for motorized pump

Housing and Operational Factors Affecting Detectors

The catalytic bead or “hot wire” sensor is the most common combustible gas detector type. Catalytic sensors have been used to detect combustible gases for more than 50 years. The accuracy and reliability of these sensors, however may be negatively impacted by a number of factors.

A combustible gas monitor should be rugged and water resistant. The size of the monitor will depend on the application for which it is used. A moisture and dust barrier should cover the sensor openings to protect the sensors from condensed moisture and excessive dust. Radio Frequency Interference (RFI) shielding should also be built into the monitor housing.

In addition to housing, the following are several of the factors known to affect the operation of a catalytic sensor:

Catalyst Poisoning

There are chemicals, which will deactivate the sensor and cause the sensor to lose sensitivity and eventually become totally nonresponsive to gases. The most common chemicals that can poison catalytic sensors are those that contain silicon (e.g., common oil and lubricants with silicon compounds used as additives in machinery). Sulphur compounds, which are often released with gases, chlorine, and heavy metals can also poison the sensor.

The only means of identifying detector sensitivity loss due to catalytic poisons is by gas-checking and calibration. When a sensor is located in an area known to contain potential poisons, it should be gas-checked at regular intervals and calibrated if necessary.

Sensor Inhibitors

Chemicals such as halogen compounds, which are used in fire extinguishers and Freon used in refrigerants will inhibit the catalytic sensor and cause it to temporarily lose the ability to function.

Sensor Cracking

The sensor, when exposed to excessive concentration of gases, excessive heat, and the various oxidation processes that take place on the sensor surface, may eventually deteriorate. Sometimes this will change the zero and span setting of the sensor.

Temperature Extremes

There is a need to have monitors operating in a wide range of temperatures. The operating range of the combustible gas monitor is typically (-20°C) to (+40°C). Sampling environments beyond these temperatures could have a negative effect on the operation of the monitor and the accuracy of response.

NOTE: NEVER store gas monitors in cold temperatures. Before testing, ALWAYS ensure the monitor has stabilized to the temperature of the atmosphere being tested.

Exposure to High Concentrations of Combustible Gas

The operating range of a combustible gas monitor is 0 – 100% of the LEL. Exposure to concentrations above this level will shorten the life of the sensor. Several manufacturers have installed a limiting device in their monitors that will disconnect the power to the sensor if exposed to high gas concentrations thereby preventing premature failure. These should not be used for leak checking.

Oxygen Content of the Gas Stream

Oxygen is required for adequate sensor operation as well as for the health and safety of workers. The measurement of oxygen is an essential part of combustible gas monitoring and a legislated requirement for Confined Space Entry. Table 2-3 provides an interpretation of the oxygen concentrations and their associated minimum requirements for personal safety.

Table 2-3 Minimum Requirements for Varied Oxygen Concentrations

OXYGEN CONCENTRATION	INTERPRETATION
23%	<ul style="list-style-type: none"> » Upper alarm set point » Flame arrestor in combustible gas monitors will NOT provide protection above this level
21%	<ul style="list-style-type: none"> » Normal percent by volume concentration of oxygen in air at Standard Temperature and Pressure (STP)
19.5%	<ul style="list-style-type: none"> » Lower alarm set point (varies by province) » Self-Contained Breathing Apparatus (SCBA) or Supplied Air Breathing Apparatus (SABA) required if working below this concentration
10 – 12%	<ul style="list-style-type: none"> » Suggested minimum oxygen concentration for accurate combustible gas monitor operation
Less than 5%	<ul style="list-style-type: none"> » Target concentration to indicate a successful purge with either inert gas (N₂, CO₂) or steam

NOTE: Even though an oxygen content of about 10% oxygen is required to obtain a valid combustible gas reading, it is recommended that any concentration below the lower alarm set point (less than 19.5%) be investigated, especially if workers will be required to enter the space.

Radio Frequency Interference (RFI)

Occasionally a monitor will go into an alarm setting when there is no gas present. This condition can be caused by RFI from portable 2-way radios and cell phones. Some manufacturers have installed RFI barriers in the instrument housing but they are not always foolproof. To test the RFI for your monitor, simply activate a radio in a safe environment alongside your monitor to see if RFI is a concern. Generally keep portable radios and other “sending” units as far away from the monitor as possible. In addition, radios and sending units must be intrinsically safe for use in a potentially flammable atmosphere.

Power Supply

Typically, fixed in place monitoring systems are powered with 110/120 volt site power. With these full time power supplies, these monitors can run continuously. Some fixed in place systems are powered by solar panels, or by batteries that are recharged with solar power. Some controllers for fixed in place monitors have an onboard fixed storage battery that provides short-term power in case of a power outage. These batteries are not intended for long-term continuous operation and often will not power the siren or other loud alarms.

Like personal monitors, fixed in place systems need to be calibrated at regular intervals. Calibration settings must meet the requirements of the worksite. See the manufacturer’s guide for general guidelines regarding calibration. Calibration of fixed in place monitoring systems must meet the manufacturer’s recommended practice. Only individuals with specific training for calibration of fixed in place monitors should attempt calibration. Failure to have a regular calibration program for fixed in place monitors is an unsafe practice.

NOTE: Batteries should NEVER be changed in a hazardous atmosphere.

Monitor Alarms

Most portable combustible gas monitors purchased today have audible, vibration, and visual alarms. Check your company policy to better understand where the alarm points should be set. Make certain that all monitors used at your site have a consistent first-alarm and second-alarm level. This can be a problem when renting additional monitors for a maintenance shutdown.

Recommended Alarm Set Points

First Alarm:

10% LEL – Pulsing tone and flashing light

Second Alarm:

20% LEL – Solid tone and continuous light

NOTE: If a monitor alarm is activated, treat it like a gas exposure. Do not assume Radio Frequency Interference (RFI).

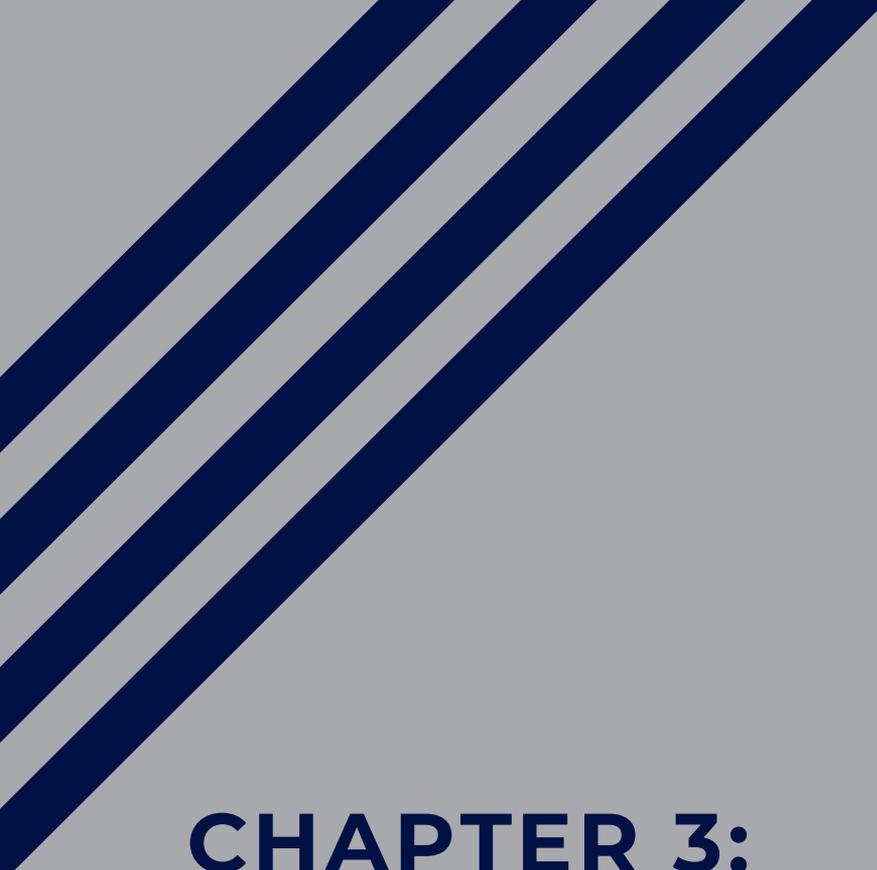
Table 2-4 Major Advantages and Disadvantages of Catalytic Detectors

ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none">» Robust» Simple to operate» Easy to install, calibrate and use» Long life with a low replacement cost» Proven technology with exceptional reliability and predictability» Easily calibrated individually to gases that cannot be detected using infrared absorption» Can perform more reliably in dusty & dirty atmospheres as they are not as sensitive as optics to the build-up of industrial contaminants» Can perform more reliably in high temperature applications» Are less sensitive to humidity and condensation» Not as significantly affected by changes in pressure» Can detect most flammable gasses	<ul style="list-style-type: none">» Catalysts can become poisoned or inactive due to contamination (chlorinated & silicone compounds, prolonged exposure to H₂S and other sulphur and/or corrosive compounds)» The only means of identifying detector sensitivity loss is by checking with the appropriate gas on a routine basis and recalibrating as required» Requires oxygen for detection» Prolonged exposure to high concentrations of combustible gas may degrade sensor performance» If flooded with a very high gas concentration, may show erroneously low or no response, and sensor may be damaged or rendered inoperable

SELF-EVALUATION / REVIEW

The following is a self-evaluation aimed at testing your understanding of the material presented in this chapter. This exercise should take approximately 15 minutes to complete. You should NOT look back on the information in this chapter nor should you look at the answer key provided. You should be able to answer a minimum of 9 of the 10 multiple choice questions correctly. You should review all the questions you have wrong by reading that part of the chapter again and/or discussing the question(s) you had wrong with your instructor prior to moving onto the next chapter.

- 1. At what % oxygen are flame arrestors designed to operate?**
 - a. Greater than 25% oxygen
 - b. Less than 15% oxygen
 - c. Greater than 23% oxygen
 - d. Less than 23% oxygen
- 2. What is the recommended first alarm set point for a combustible gas monitor?**
 - a. 10% LEL
 - b. 15% LEL
 - c. 20% LEL
 - d. 25% LEL
- 3. What is the recommended second alarm set point for a combustible gas monitor?**
 - a. 10% LEL
 - b. 15% LEL
 - c. 20% LEL
 - d. 25% LEL
- 4. Which of the following operational factors do NOT affect the accuracy of combustible gas monitors?**
 - a. Extreme temperature
 - b. Sampling above ground level
 - c. Exposure to high concentration of combustible gas
 - d. Exposure to condensed moisture
- 5. What is the normal operating temperature range for a combustible gas monitor?**
 - a. - 40°C to + 40°C
 - b. - 20°C to + 40°C
 - c. - 40°C to + 20°C
 - d. - 20°C to + 20°C
- 6. What is the operating range of a combustible gas monitor?**
 - a. 0 – 100% UEL
 - b. 0 – 20% LEL
 - c. 0 – 20% UEL
 - d. 0 – 100% LEL
- 7. How are samples drawn into the sensors of an active or sample draw system of a combustible gas monitor?**
 - a. By placing the monitor between one self and the source
 - b. By a hand aspirator or motorized sample draw system
 - c. By converting the gas reading picked up by the controller and sensing this signal
 - d. Through osmosis generated by the filtering system and the active filament
- 8. What is the key element of a combustible gas monitor?**
 - a. The catalytic sensor
 - b. The sample draw system
 - c. The housing
 - d. The display
- 9. Which of the following is a disadvantage of a passive combustible gas monitor?**
 - a. Can be converted into an active system with attachments
 - b. Potential sample loss in hose due to leaks, condensation and absorption
 - c. Worker may be exposed to a potential contaminated environment
 - d. Requires power supply for motorized pump operations
- 10. Which one of the following best describes the interpretation of 10-12% Oxygen concentration in the gas stream?**
 - a. Flame arrestors will not provide protection above this level
 - b. SCBA/SABA is not required for work
 - c. Normal percent by volume of oxygen in the air at STP
 - d. Minimum oxygen concentration for accurate combustible gas monitor operations



CHAPTER 3:

Care and Preparation of Combustible Gas Monitor



OUTCOME

Describe the minimum care and preparation required to operate a combustible gas monitor.



OBJECTIVES

1. Conduct a Calibration Check of a gas monitor.
2. Explain calibration strategies of a gas monitor.

INTRODUCTION

Every day, workers in the oil and gas industry face the invisible threats of flammable, toxic, irritant, and asphyxiating compounds found lurking in the workplace, especially in confined spaces. Dangerous conditions involving unsafe oxygen levels, as well as toxic and combustible gases are of major concern given their potential for physical and material damage. Many of the dangers associated with hydrocarbon compounds are not visible, nor accurately detectable through any of the five human senses. Therefore, a good way to significantly improve the safety of oil and gas workers is through the use of gas-monitoring instruments (also referred to as gas detectors or gas sensors) designed to detect and alert users of potential flammable, toxic, and asphyxiating dangers.

Gas detectors are life saving devices. They are precision instruments that are built solely to measure and monitor potentially lethal gases in the workplace.

Purchasing or renting the appropriate gas detector and having it at the workplace is just the first step in developing a combustible gas detection program. The only way to ensure that a gas detector will accurately and reliably respond to the hazardous gas or gases it is designed to detect, however, is to test it against a known gas standard. Exposing the instrument to a known concentration of test gas will show whether the instrument responds accurately and reliably. A second method of verifying gas detector accuracy and reliability is to conduct a full calibration of the instrument. Each method is appropriate under certain conditions and better explained in the following sections.

Function (Bump) Test Versus Calibration

Function Test/ Qualitative Function Check

A function test, also referred to as a “Bump Test” or a “Go – No Go test”, is a field test that verifies calibration by exposing the instrument to a known concentration of test gas. The instrument reading is compared to the actual concentration 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. It is recommended that users check with the gas detection equipment manufacturer for acceptable tolerance ranges.

When performing a Bump Test, the gas detector should be “zeroed” to give a more accurate picture of the Bump Test results. Also, the test should be conducted in a clean, fresh air environment. When performing a Bump Test, the test gas concentration should be high enough to trigger the instrument alarm. If the instrument fails the test, it must be adjusted through a full calibration before it is used. If the instrument fails the Bump Test, it should be returned to a qualified person or calibration facility for a more complete inspection and re-calibration.

NOTE: A gas detector’s response to a test gas should be within +/- 10% of the LEL value equivalent to the % volume listed on the calibration test gas cylinder for the gas being tested.

Reasons for Inaccurate Readings or Failed Bump Tests

The instrument’s response to calibration gas exposure is known as its “reference point,” or the point where all gases will be measured and compared. When an instrument’s reference point shifts, its readings also shift and become inaccurate. This is known as “calibration drift,” and can be caused by chemical degradation of sensors, drift in electronic components, exposure to extreme environmental conditions, exposure to high concentrations of target gases, or exposure to poisons and inhibitors.

In order to minimize the likelihood of a failed Bump Test, it is imperative that the appropriate procedures be followed.

Calibration Check

A Quantitative test utilizing a known traceable concentration of test gas to demonstrate that the sensor(s) and alarms respond to the gas within manufacturer’s acceptable limits. This is typically $\pm 10-20\%$ of the test gas concentration applied unless otherwise specified by the manufacturer, internal company policy, or a regulatory agency. Table 3.1 provides the necessary steps needed to conduct a calibration check on a combustible gas detector.

Time Weighted Average (TWA) values are calculated by taking the sum of the exposure during a workday to a particular toxic contaminant in terms of parts-per-million hours and dividing by an eight-hour period.

Short Term Exposure Limits (STEL) Toxic substances may have short-term exposure limits, which are higher than eight hour TWA. The STEL is the maximum average concentration to which an unprotected worker may be exposed in any fifteen-minute interval during the day.

Peak Readings

The instrument stores the highest detected gas reading, the “peak reading” or “peak”. Bump testing and calibration will often register new peak readings. Therefore, the clearing of the peak reading should follow each calibration. The instrument operator may also wish to clear the peak reading after a bump test, before a change in location, or after an alarm is addressed and cleared.

NOTE: The peak readings and the data log readings are stored independently of one another; therefore, clearing the peak reading does not affect the data log. Powering the instrument off or changing its battery does not affect the peak reading. These checks and balances help promote operator safety, and serve to contain the peak readings in a “black-box” manner. In the event of a gas-related incident, this black-box record can be useful to the safety team or a prospective investigator.

Managing Gas Monitor Data

Safety managers do not want to spend time managing instrument data, so gas detection providers are finding ways to efficiently manage the data for them. A docking station, for example, can perform all of the essential tasks related to a gas monitoring program – automatically. It can carry out a functional “Bump” Test, calibrate the gas monitor, track and record essential data such as gas concentration levels over a period of time, and charge the batteries that power the gas detectors. A docking station can manage a whole fleet of gas detectors in this way. This can save the safety manager and his/her team a lot of time.

A data-logging monitor can help the safety manager avoid confrontation through proper documentation. In the case of a safety event where evidence of proper maintenance and care of a gas detector must be given, docking stations provide objective proof that procedures are being followed.

Accurate recordkeeping provides evidence of

Table 3-1 Combustible Gas Monitor Calibration Check Procedure

STEP	DESCRIPTION
1. Check Record Log	» Check status and past history of the gas detector
2. Prepare Gas Detector	<ul style="list-style-type: none"> » Carry out pre-use inspection by visually inspecting the gas detector for damage, missing components and cleanliness. » Turn power on and warm-up gas detector. (Follow manufacturer’s instructions) » Check battery » Carry out leak test (Active Monitors Only)
3. Zero Gas Detector	» Follow manufacturer’s instructions
4. Check Gas Detector Response	<ul style="list-style-type: none"> » Flow test gas to gas detector 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 Calibration Check	<ul style="list-style-type: none"> » Use a bound log or notebook (see Activity 3.1) » 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
<p>NOTE OF CAUTION! Gas Detectors failing this procedure should be removed from use tagged and sent to a repair facility for calibration immediately.</p>	

the event as well as proof that proper testing and maintenance tasks were carried out. This due diligence of data collection and retention may help avoid long and costly litigation.

Each year, docking station capabilities increase through enhancements to the software package, which currently allows users to import event logs, Bump Test and calibrate results, log data from detectors and base stations, produce detector status reports, generate Bump Test certificates and calibration certificates, manage users and base stations, configure detectors, and archive and save the database. Although some do not require a computer to operate, docking stations can be remotely connected to a network and regularly downloaded in standard Excel format for efficient recordkeeping. Even in situations in which computers may not be available, Bump Tests must be performed and data captured.

NOTE: ALWAYS ensure you are in a clean environment while conducting a function test, calibration check or zeroing the monitor.

ACTIVITY 3-1

Working in small groups, follow the procedures in Table 3-1 to conduct a calibration check. Record your findings in the chart below.

Make: _____ Model: _____

Serial Number: _____ Calibration Gas: _____ Date: _____

DATE	TEST GAS	TEST RESULTS		ALARMS		USER NAME	INITIALS
		EXPECTED	ACTUAL	1ST	2ND		

Table 3-2 Function Testing Frequency – Guidelines

EXPECTED USE	RECOMMENDED FREQUENCY (MINIMUM)
Daily Use	Bump Test at start of each shift.
Scheduled Hazardous Operation	Bump Test 24 hours before use and at the start of the shift. (This ensures availability when needed.)
After Rough Treatment	Send for calibration before re-use (Bump Test may not identify all damage).
Emergency Response	Bump Test at least once per month and prior to use (company policy may differ).

Full Calibration of Combustible Gas Monitors

A full calibration goes a step further than a functional test. A full calibration ensures maximum accuracy of the instrument is performed successfully. Calibration of any gas detector should be performed by a competent individual.

Calibration Frequency

Gas detectors need to be calibrated and periodically checked to ensure their accuracy and integrity. The intervals between calibrations can be different depending on the type of gas detector being used. Additional factors influencing calibration frequency also include local standards, level of risk involved, company policies, and industry best practices. Generally, the detector manufacturer will recommend a time interval between calibrations.

However, it is good general practice to check the detector more closely during the first 30 days after installation of a fixed monitor. During this period, it is possible to observe how well the device performs in the new environment. Most problems – such as an inappropriate sensor location, interference from other gases, or the loss of sensitivity – will surface during this time. During a period of initial use of at least 10 days in the intended environment, calibration of fixed monitors should be verified daily to ensure nothing is in the atmosphere to poison the gas detector. The period of initial use must be of sufficient duration to ensure the sensors are exposed to all conditions that might adversely affect the sensors. If the tests demonstrate that no adjustments are necessary, the interval between checks may be lengthened, but it should not exceed 30 days. If the instrument fails a Bump Test, it must be adjusted through a full calibration before it is used. When calibrating an instrument, always follow the manufacturer's recommended calibration frequency and procedure.

Calibration

The calibration of the majority of commercial gas sensors can be executed by the product supplier or by the user. A calibration performed by the supplier requires a standard fee, to which the shipping cost of the sensor must be added. If the sensor cannot be shipped, or requires a specific calibration in situ, an operator actually performing the calibration is required and the related cost must be taken into account. A calibration executed by the user does not involve any fee but requires the purchase of a calibration kit appropriately created for the management of the sensor.

Standard Method

The standard calibration method involves two steps: setting the “zero” reading (offset) and calibrating the span. The “zero” reading refers to the ideal condition in which the gas detector's target molecule is completely absent (e.g., pure nitrogen atmosphere for an oxygen sensor), while the span calibration requires a controlled atmosphere with a fixed rate of detector's target molecule (e.g. flowing standard air with 20.9% O₂ for an oxygen sensor). Standard calibration kits allows the user to simulate the “zero” reading condition flowing inert gas to the sensor (providing a proper pure gas can) or alternatively setting the reading in vacuum (providing vacuum pump and related equipment). For the span calibration, standard kits also provide a gas can containing a premixed atmosphere to be flown to the sensor. Using premixed atmosphere cans is the fastest and easiest way to perform a standard calibration. This method however suffers two major downsides:

- » Accurate calibrations require more than 1 point for the span regulation, thus an expansive set of gas cans, each containing a different atmosphere, is needed.
- » Calibration of custom gas sensors may require specific atmospheres not commercially available.

Calibration Gas

The most important tool for accurate calibrations is the test gas itself. Always ensure that the gas cylinder has not reached its expiration date before calibration. The type and concentration of the gas, sample tubing, regulators, and calibration adapters must be appropriate for the instrument and sensors. Combustible gas sensors are non-specific and can be calibrated to any number of different gases. Choose the calibration gas that most closely matches the gas that will be encountered. If not known or if a mix of gases is suspected, then calibrating with pentane or methane gas is recommended. Using pentane or methane as calibration standards will allow the sensor to detect a larger group of hydrocarbons commonly found in the oil and gas sector. Today, many multiblend cylinders of gas are manufactured to simplify the task of calibrating multi-gas detectors. For this, you will need to match the cylinder contents to the sensors installed and make sure the concentrations are sufficient to activate the instrument alarm set points.

Gases that are commonly used include pentane, methane, propane and hexane. Table 3.3 illustrates some of the common options used for selecting a specific calibration gas.

Table 3-3 Calibration Options for Combustible Gas Monitoring

EXPECTED USE	CALIBRATION GAS
Sampling a specific flammable gas/vapour	Calibrate to that specific gas/vapour.
General purpose, where flammable gas is primarily methane	Calibrate with methane.
General purpose, where methane is a minor component (if present at all)	Calibrate with pentane, propane, or hexane to increase sensitivity.

NOTE: The gas used to calibrate the monitor should be identified on the monitor.

Calibration Procedure

The calibration procedure includes both a zero calibration (fresh air calibration) and sensor calibration with known concentrations of gas (span calibration).

- » Zero calibration is performed to establish baseline readings of atmospheres that are known to be free of toxic and combustible gases.
 - Baseline readings are zero for carbon monoxide, hydrogen sulphide, combustibles and 20.9% for oxygen.
- » Span calibration is the adjustment of the gas monitors response to match that of a known concentration of gas. Sensors can lose sensitivity through normal degradation, exposure to high gas concentrations or sensor poisoning.
 - The Span calibration is performed to ensure the gas monitor detects the target gases within specific operating parameters.

Reactive Gas Mixtures

Reactive gas mixtures are calibration gas mixtures that include at least one component gas which is classified as reactive. This is a broadly used term for chemicals that have some instability under certain conditions, and may react with certain materials, moisture, oxygen, or other chemicals. Reactive gas mixtures include mixtures containing hydrogen sulfide, chlorine, sulfur dioxide, ammonia, hydrogen chloride, among others. Reactive gas mixtures are generally packaged in a special cylinder made of aluminum and treated by a special process to minimize reactivity with the reactive gas. Reactive gas mixtures typically have a shelf life of one year or less. After shelf life has expired, it is likely that the concentration of the reactive gas will either decrease or eventually disappear all together.

Non-Reactive Gas Mixtures

Non-reactive gas mixtures are calibration gas mixtures that do not include any reactive gases. This is a broadly used term for chemicals that are stable under most conditions, and are not affected by moisture, oxygen, or other chemicals. Non-reactive gas mixtures include mixtures containing alkane or alkene hydrocarbons (methane, ethane, propane, hexane, isobutylene, etc.), nitrogen, hydrogen, carbon monoxide, carbon dioxide, among others. Non-reactive gas mixtures are generally packaged in a cylinder made of steel. Non-reactive gas mixtures have a shelf life of three years.

Shelf Life for Gas Cylinders

As a general rule, all steel cylinders have a 3-year shelf life while aluminum cylinders range from 6-13 months. Table 3-4 provides the shelf life of various gas mixtures.

Table 3-4 Shelf Life of Reactive and Non-Reactive Gases

GAS MIXTURES CONTAINING	SHELF LIFE
HCN, NH ₃ , SO ₂ , NO, PH ₃ , SiH ₄	12 months
H ₂ S	2 years
Cl ₂	9 months
HCL	8 months
NO ₂	6 months
All non-reactive gas mixtures	3 years

SELF-EVALUATION / REVIEW

The following is a self-evaluation aimed at testing your understanding of the material presented in this chapter. This exercise should take approximately 5 minutes to complete. You should NOT look back on the information in this chapter nor should you look at the answer key provided. You should be able to answer all 5 of the multiple-choice questions correctly. You should review all the questions you have wrong by reading that part of the chapter again and/or discussing the question(s) you had wrong with your instructor prior to moving onto the next chapter.

1. Which of the following may be considered satisfactory (using a 50% LEL test gas) to indicate an acceptable function test?

- a. 65-75% LEL
- b. 45-55% LEL
- c. 24-45% LEL
- d. Less than 20% LEL

2. What is the recommended frequency to function test a combustible gas monitor?

- a. Start of each shift, if used daily
- b. Weekly, if used for scheduled hazardous operations
- c. Monthly, if used roughly
- d. Annually, if used for emergency response

3. For general gas monitoring purposes where methane is a minor component, which one of the following gases should a combustible gas monitor be calibrated for?

- a. Butane or Hexane
- b. Methane or Pentane
- c. Propane or Hexane
- d. Pentane or Butane

4. For general-purpose use, what gas should be used in calibrating a combustible gas monitor?

- a. Propane
- b. Methane
- c. Hexane
- d. Pentane

5. List the five basic steps for conducting a function check on a combustible gas monitor.

- 1. _____

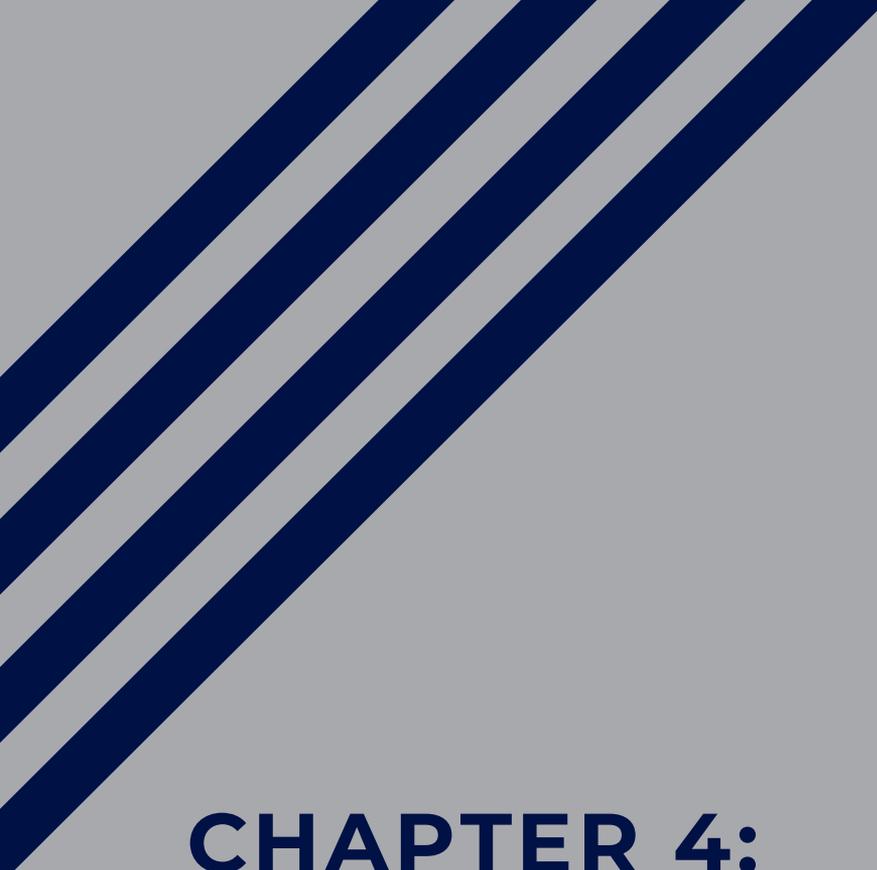
- 2. _____

- 3. _____

- 4. _____

- 5. _____

NOTES



CHAPTER 4:

Sampling Strategies and Interpretation of Monitor Readings



OUTCOME

Explain sampling, interpretation of results and application of correction factors to gas monitor readings.



OBJECTIVES

1. Explain sampling strategies for quantitative and qualitative assessments.
2. Describe the relationship between the LEL, explosive range and UEL of a combustible gas/vapour.
3. Explain the correction factor for a combustible gas monitor.

INTRODUCTION

Flammable gas detection tools such as gas detectors may be used whenever there is the possibility of a hazard to life or property caused by the accumulation of a flammable gas-air mixture. Such apparatus can provide a means of reducing the hazard by detecting the presence of the flammable gas and issuing suitable audible or visual warnings. Gas detectors may be used to initiate specific precautions (for example plant shutdown, evacuation, and operation of fire extinguishing procedures). In order for combustible gas detectors to be effective at enhancing the safety of workers, however, the appropriate sampling strategies and procedures must be followed. Furthermore, a solid understanding of quantitative and qualitative assessment methodology plus familiarity with the explosive and flammable ranges of various combustible gases is required.

Hazard Assessment

To monitor the presence or concentration of a gas the installation of a gas detection system is typically required. Such a system prevents harmful gases from damaging the environment, saves on operational costs, and most importantly maximizes the safety of staff and the public alike. Forming part of a gas detection system, there are two types of assessments commonly used on worksites:

- » [Qualitative Assessment](#)
- » [Quantitative Assessment](#)

Qualitative Assessment

The word qualitative refers to descriptions or distinction based on some quality or characteristic rather than on some quantity or measured value. The term qualitative may be used to indicate the following:

- » Qualitative property, a property that can be observed but not measured numerically
- » Qualitative research, featuring a high degree of subjectivity
- » Qualitative data, data that is not quantified

A qualitative assessment allows the operator to use his/her knowledge and in particular his/her senses to initially determine if gases could be present in concentrations that would be hazardous to people and the environment. A qualitative assessment does not provide a measure of the presence of gases or vapours in the air but it is the first step in deciding whether quantitative measuring needs to occur. Sometimes the hazard assessment stops at this point and the appropriate corrective actions are implemented.

EXAMPLE: You open your basement door and see furniture floating around. Do you really need to measure the depth of the water or do you call a plumber?

Pegging

A qualitative assessment will assist you in deciding where to start measuring for gas and thereby avoid turning a monitor on too close to the source which can over-range the monitor or result in the monitor displaying a zero reading (called pegging).

A common response of catalytic combustible gas monitors where a high hydrocarbon gas concentration causes a rapid rise and fall to zero reading. If the monitor display is not watched continuously, the zero reading may mistakenly be interpreted as meaning no gas or vapour is present.

Quantitative Assessment

The term quantitative refers to a type of information based in quantities or else quantifiable data (objective properties)—as opposed to qualitative information, which deals with apparent qualities (subjective properties). It may also refer to:

- » Quantitative Research, scientific investigation of quantitative properties
- » Statistics, also known as quantitative analysis
- » Numerical data, also known as quantitative data

Quantitative assessment therefore is the actual measurement of the contaminants in the air that is used to support the qualitative assessment and provide some values to confirm or reject the assumption that a safe working environment exists. In order to conduct a quantitative assessment, a calibrated detection device or monitor operating in the appropriate range is required. A trained operator using an approved sampling strategy is necessary to ensure that the concentration values are representative of the actual contamination.

SAMPLING STRATEGIES FOR QUANTITATIVE ASSESSMENT

Types of Sampling

The value of a combustible gas monitor is its ability to display the % lower explosive limit (LEL) of the combustible gas in the atmosphere at the time of sampling. There are two types of sampling that can be used to provide information to workers about the % LEL of combustible gas:

- » Intermittent Sampling
- » Continuous Sampling

Intermittent Sampling

Intermittent sampling is used to sample the air and inform the operator about the concentration of flammable substances at the time and place where the sample was taken. The sampling takes place at different times during a work period and therefore it is non-continuous. Intermittent sampling can be achieved through a timed schedule such as every five minutes or every hour depending on the information needs. Intermittent sampling can also be initiated whenever a job function changes (e.g., when entering a tank or disturbing sludge), or when the potential for safety risks increases (e.g., change in wind direction).

Continuous Sampling

Continuous sampling means that a sampling gas is being monitored all the time, and in most cases, the gas concentration displayed reflects what is truly happening in real time. Therefore, this sampling method provides “real” time information about the % LEL of the combustible gas being monitored at the worksite. Compared to intermittent sampling, continuous sampling can be more reliable and can allow the user to identify gas concentration variability and establish trends. Whether intermittent or continuous sampling is carried out will be influenced by a number of factors including industry standards, regulations, and the toxicity or explosive nature of the contaminant/gas being monitored. In a situation in which the contaminant source is expected to change fairly quickly continuous sampling would be preferred.

Strategies for Sampling

Two common methods used to inspect the worksite for potential combustible gas hazards:

- » Grid/Matrix Strategy
- » Spoke and Wheel Strategy

Both strategies are robust and lend themselves to a comprehensive evaluation of the entire workspace area being monitored.

Grid or Matrix Sampling Strategy

A grid or matrix sampling strategy can be used to ensure all areas of interest are sampled and that all subsequent sampling covers the same areas previously tested. By comparing gas concentration in the same locations over time one is able to identify concentration variability and establish trends. Figure 4.1 provides a schematic diagram for a grid or matrix sampling strategy.

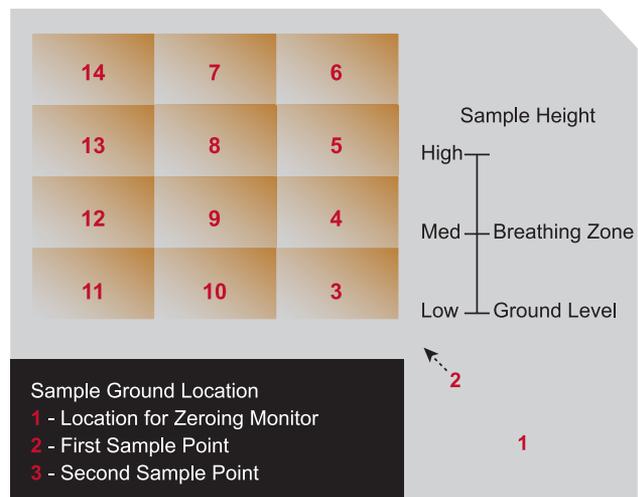


Figure 4-1 Grid (Matrix) Sampling Design Strategy

Spoke and Wheel Strategy

The Spoke and wheel strategy is best used when the source of gas is known. When implementing this strategy, one must identify an area where the gas concentration being monitored is zero. This can be accomplished by sampling upwind or at a distance far enough where the gas being monitored does not exist. Turning a monitor on too close to the source could result in inaccurate readings placing the operator in a dangerous situation.

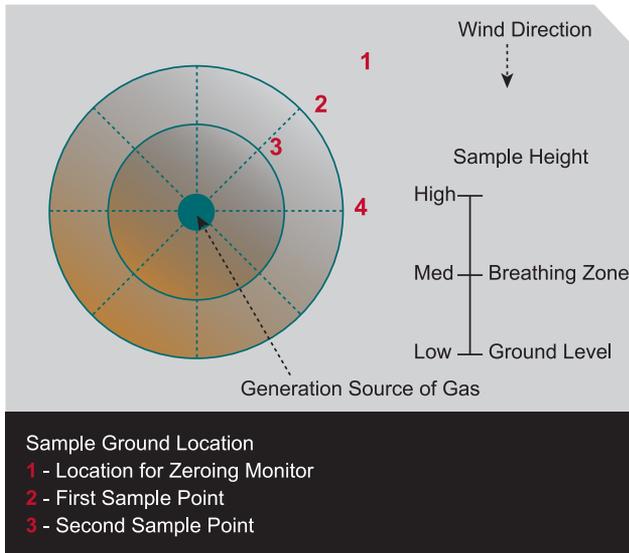


Figure 4-2 Spoke and Wheel Sampling Design Strategy

Sampling Procedures

Usually, the type of sampling required is dependent upon the following:

- » Work being performed
- » Potential interferences from adjacent work areas
- » Type of monitors in use
- » Ability of the operator to interpret the information after it is gathered
- » The need for all of the necessary information

In some situations, the workers and operators may identify a hazardous worksite without the use of a combustible gas monitor. An example may include workers noticing a gas leaking from a valve.

If a worker decides that a combustible gas monitor is required to complete the initial hazard assessment or confirm that work procedures and policies are effective, the individual will have to carry out the following:

1. Select the appropriate monitor (passive or active sampling).
2. Function test (bump test) the monitor.
3. Determine sampling strategy and a start point for the sampling.
4. Perform the sampling in a structured manner to avoid missing “hot spots”.
5. Record the readings from the identified sample spots (use a sketch or site grid map).
6. Interpret the information in order to inform workers whether the worksite is safe or unsafe. For example:
 - Can work start or continue?
 - Do you need controls to reduce the concentration or exposure before work can start?
 - Do workers need to wear SABA or SCBA?
 - Has the concentration risen or fallen from the previous sampling?
 - When should resampling take place?

Keeping Gas Concentrations to a Safe Level

Operational Range of a Combustible Gas Monitor

The operational range of a combustible gas monitor is from 0 – 100% LEL. The following chart depicts the % volume of common gases required to achieve 100% LEL.

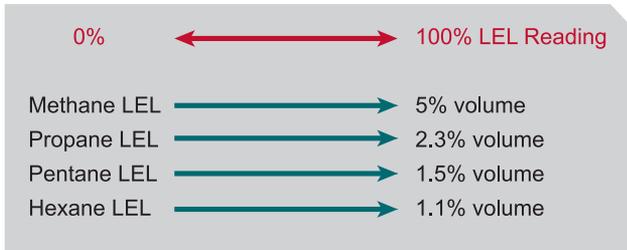


Figure 4-3 Operational range of a combustible gas monitor

A combustible monitor calibrated to one flammable substance will normally detect the presence of another flammable substance. However unless the calibration gas is the same as the sampled gas, the gas detection accuracy will suffer. When reporting a combustible gas concentration, the gas used to calibrate the instrument should also be mentioned. Readings can be as much as half or double the actual percent LEL.

Safe Gas Working Levels

As illustrated in the Table 4-1, safe gas working levels have been established to provide protection for workers, property, environment and the public. When significant LEL level increases are observed, work should stop and a further evaluation should be conducted to determine if additional controls are necessary to maintain a safe work environment. Determining whether the work environment is safe will be influenced by many factors including whether hot or cold work is being performed.

Hot Work

Hot work involves the use of flame or the possibility of producing sparks. This includes the use of non-classified electrical equipment, internal combustion engines, and other work such as cutting, welding, burning, air gouging, riveting, drilling, grinding or chipping.

Cold Work

Cold work is defined as work that does not involve the use of flame, flammable substances or the possibility of producing sparks.

Table 4-1 Suggested Target Work Range

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 SCBA/SABA	No Hot Work
20% LEL (+)	Emergency Measures ONLY	No Hot Work

*When flammable gases or vapours are less than 10% LEL, the occupational exposure levels of other substances may be exceeded and therefore respiratory protection would be required.

Explosive Range of Combustible Gases/Vapours

Methane

To understand % LEL, consider an experiment where several concentrations of methane and air mixtures are created. Each mixture is then subjected to a source of ignition. The likely occurrence of an explosion or fire during these tests is depicted in Figure 4-4 where % air is displayed on the vertical axis and % methane is displayed on the horizontal axis.

As depicted in Figure 4-4, a fire or explosion does not occur until a 5% volume of methane in the air is reached. The reason for this is that 5% volume is the LEL for methane. Continuing on with the experiment, a fire and explosion occurs at each interval from 5% onward until a methane concentration of 15% is reached. Methane's Upper Explosive Limit (UEL) is 15%.

In summary, the explosive range for methane is 5% to 15% volume. Therefore, for a methane-calibrated instrument, the range 0 – 100% LEL is equivalent to an actual methane concentration range of 0 – 5% volume.

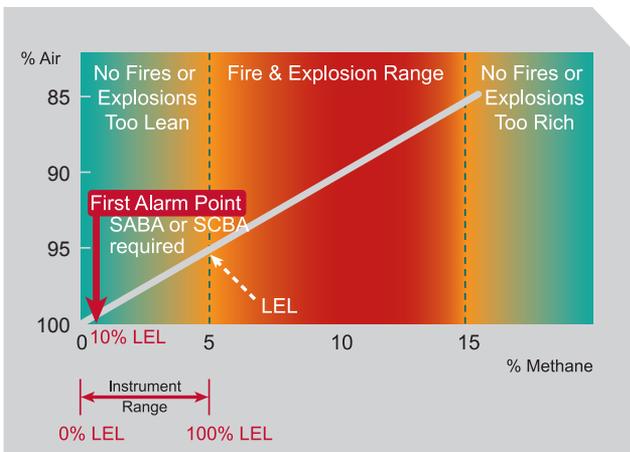


Figure 4-4 Explosive Range of Methane with Operational Range of Detector/Instrument

NOTE: at 10% LEL, SABA or SCBA is required.
At 20% LEL, no entry is allowed.

Explosive Range for Methane and Other Combustible Gases

Lower and Upper Explosive Limits (LELs and UELs) also exist and differ for many other combustible gases. Examples of combustible gases and their LEL/UEL are provided in Table 4-2.

Table 4-2 Lower and Upper Explosive Limits of Flammable Substances

GAS/VAPOUR	EXPLOSIVE LIMITS (% IN AIR)	
	LEL (100% LEL)	UEL
Methane	5.3	15
Ethane	3	12.5
Propane	2.3	9.5
Pentane	1.5	7.8
Butane	1.9	8.5
Hexane	1.2	7.5
Toluene	1.27	7.0
Hydrogen	4	74
Hydrogen Sulphide	4	46
Carbon Monoxide	12.5	74

As demonstrated by the values presented in Table 4.2, different gases have different LELs and UELs. Propane, for example, has a LEL and an UEL of 2.3 and 9.5, respectively while methane has a LEL and an UEL of 5.3 and 15, respectively.

NOTE: When communicating the results of a gas test, it is important to report the combustible gas used in calibrating the monitor, i.e. % LEL – Methane. Without this information, it would be difficult to interpret or duplicate the test.

Correction Factors

Correction Factors in Combustible Gas Measurements

A correction factor is the amount of deviation in the combustible gas monitor measurement that is accounted for in the calibration process.

Gas detectors can be used for the detection of a wide variety of combustible gases and vapours that exhibit different responses. Therefore, smaller molecules like hydrogen and methane are substantially more sensitive than heavy components like kerosene. The best way to calibrate any sensor to different compounds is to use a standard of the gas of interest. However, correction factors have been determined that enable the user to quantify a large number of chemicals using only a single calibration gas, typically methane or pentane. Correction factors can be used in one of three ways:

1. Calibrate the unit with methane in the usual fashion to read in methane % LEL equivalents. Manually multiply the reading by the correction factor to obtain the % LEL of the gas being measured.
2. Calibrate the unit with methane and then call up the correction factor from the instrument memory or download from a personal computer. The unit will then read directly in % LEL of the gas of interest.
3. Calibrate the unit with methane, but input an equivalent, “corrected” span gas concentration when prompted for this value.

Table 4-3 provides a list of correction factors for a typical catalytic combustible gas monitor calibrated on methane.

Table 4-3 Correction Factors for a Methane-calibrated Instrument

GAS/VAPOUR	METHANE CORRECTION FACTOR
Methane	1.0
Propane	1.6
Hydrogen	1.1
Pentane	1.9
Toluene	1.4

NOTE: These values may change depending on manufacturer.

Limitations of Correction Factors

Manufacturers generally provide a set of correction factors that allow the user to measure different hydrocarbons by simply multiplying the reading by the appropriate correction factor to obtain the reading of a different gas. However, it should be noted that the correction factors are a set of numbers that should be used with great care. The correction factors can vary from sensor to sensor, and they can even change on the same sensor as the sensor ages. Therefore, the best way to obtain precise readings for a specific gas is to actually calibrate the sensor to the gas of interest directly.

Some limitations of correction factors are as follows:

- » To apply correction factors properly, the operator must have knowledge of the composition of the gas atmosphere that he/she is testing. This is often difficult information to obtain, especially in an emergency response situation.
- » Correction factors quoted by the manufacturer are valid only on relatively new sensors. As the sensors age, their correction factors change.
- » The age of the sensor is based on usage and gas exposure not time.

Catalytic sensors are most commonly calibrated to methane for 0 – 100% LEL full-scale range using 50% LEL test gas. (see Table 4-4 for an example using 50% LEL test gas).

Table 4-4 Relative Gas Sensitivity

EXAMPLE: RELATIVE SENSITIVITY OF A TYPICAL SENSOR CALIBRATED FOR 100% LEL METHANE GAS	
Gas	Reading
Methane	100%
Propane	60%
n-Butane	60%
n-Pentane	50%
n-Hexane	45%
Methanol	100%
Ethanol	70%
Isopropyl Alcohol	60%
Acetone	60%
Methyl Ethyl Ketone	50%
Toluene	45%

Catalytic Combustible Gas Monitor Responses

The following exercise has been designed to demonstrate the response differences when catalytic gas monitors are calibrated for different gases and used interchangeably. The monitors will be calibrated to:

- » 50% LEL Methane (2.6% vol.),
- » 50% LEL Propane (1.1% vol.), and
- » 50% Pentane (0.7% vol.) or 50% Hexane (0.6% vol.).

The objective is to provide an opportunity to apply the previous information on correction factors by showing:

- » How correction factors convert a methane-calibrated monitor reading to a value closer to that of the combustible gas concentration being tested,
- » That combustible gas monitor readings are only accurate when gas concentrations are zero or the monitor is monitoring the gas to which it was calibrated, and
- » That although a monitor reading of other gases may be inaccurate, a methane-calibrated monitor will still provide adequate warning at a 10% LEL concentration.

SELF-EVALUATION REVIEW

The following is a self-evaluation aimed at testing your understanding of the material presented in this chapter. This exercise should take approximately 10 minutes to complete. You should not look back on the information in this chapter nor should you look at the answer key provided. You should be able to answer a minimum of 13 of the 16 multiple choice questions correctly. You should review all the questions you have wrong by reading that part of the chapter again and/or discussing the question(s) you had wrong with your instructor prior to moving onto the next chapter.

- 1. What are two (2) types of hazard assessment used on a worksite to determine if a hazardous combustible or toxic gas condition exists?**
 - a. Quantitative and Analytical
 - b. Qualitative and Analytical
 - c. Quantitative and Qualitative
 - d. Traditional and Analytical

- 2. What are the two types of intermittent sampling used to provide information to workers about the concentration of combustible gas?**
 - a. "Grid" and "Spoke and Wheel"
 - b. "Intermittent" and "Continual"
 - c. "Qualitative" and "Quantitative"
 - d. "LEL" and "VEL"

- 3. Following an acceptable functional test of your combustible gas monitor, what is the next step in ensuring an accurate combustible gas reading?**
 - a. Perform sampling in a structured manner
 - b. Start sampling downwind of the area to be monitored
 - c. Determine a start point for the sampling that is upwind or crosswind and where the concentration of gas should be zero
 - d. Start in an area you suspect is the hot spot in order to determine the exact amount gas concentration

- 4. What steps should you take to determine if the concentration of gases has risen or fallen?**
 - a. Carry out another sampling in the reverse order of the previous sampling
 - b. Place the monitor at the location of the hot spots and monitor for at least 10 minutes
 - c. Set the monitor to the previous LEL level of gas concentration and carry out another sample
 - d. Duplicate the sampling strategies as per the sketch or site grid map used on the previous sample

- 5. In order to properly interpret or duplicate the results of a gas test, what information should you include in your findings?**
 - a. Results of the function check
 - b. The correction factors used in the test
 - c. The combustible gas used in calibrating the monitor
 - d. The LEL settings of the monitor

- 6. Which of the following statements best describes the combustible gas monitor?**
 - a. Combustible gas monitors are safety instruments designed to provide analytical information
 - b. Combustible gas monitors are instruments designed to reliably determine whether an explosive gas condition exists
 - c. Combustible gas monitors are instruments designed to measure the quantity and type of gases present in the worksite
 - d. All combustible gas monitors are calibrated using methane

- 7. What can occur if a combustible gas monitor is turned on too close to the source of the combustible gas?**
 - a. Will void the use of correction factors
 - b. Can cause pegging which might result in operator mistakenly interpreting the monitor reading of zero as no flammable gas
 - c. Can cause the LEL set points to read in error and cause the operator to mistakenly interpret the actual LEL readings
 - d. Can cause the monitor to operate above its calibrated operating range resulting in the operator mistakenly interpreting the monitor's true readings

- 8. What is required to conduct qualitative assessment?**
 - a. A calibrated detection device
 - b. Correction factors
 - c. The human senses
 - d. The type of gas used in calibrating the monitor

- 9. What is required to carry out a quantitative assessment?**
 - a. A calibrated detection device
 - b. The human senses
 - c. Correction factors
 - d. Combustible gas monitors are calibrated using methane

10. What information is provided by a combustible gas monitor?

- a. The % LEL of the combustible gas in the atmosphere at the time of testing
- b. The level of combustible gas in the atmosphere in terms of LEL and UEL
- c. The amount of combustible gas in the atmosphere measured in terms of % of that gas in the atmosphere
- d. Whether a combustible atmosphere exists in terms of the type of gas present in the atmosphere at the time of testing

11. Why is intermittent sampling used?

- a. To sample the air and provide real time information about the % LEL of the combustible gas in the workplace
- b. To select the appropriate monitor
- c. To sample the air and inform the operator of the concentration of flammable substances at the time and place the sample was taken
- d. To determine the potential interference from adjacent work areas where monitoring of flammable substances may or may not be present

12. Which of the following statements best describes continuous sampling?

- a. Samples the air and inform of the concentration of flammable substances at the time and place the sample was taken
- b. Determine the potential interference from adjacent work areas where monitoring of flammable substances may or may not be present
- c. Sample the air and provide real time information about the % LEL of the combustible gas in the workplace
- d. A sampling strategy used when correction factors are known

13. What is the operating range of a combustible gas monitor?

- a. Same as the explosive range of the gas being tested
- b. 0 – 100% UEL
- c. 0 – 100% LEL
- d. 0 – 15% of the volume of gas to which the monitor was calibrated

14. What is a correction factor?

- a. A ratio of a monitor response to known gas compared to the gas it was calibrated to
- b. A ratio of a monitor response to methane gas compared to the gas it was calibrated to
- c. A ratio of a monitor response to propane compared to the gas it was calibrated to
- d. A ratio of a monitor response to known gas compared to the gas in the atmosphere

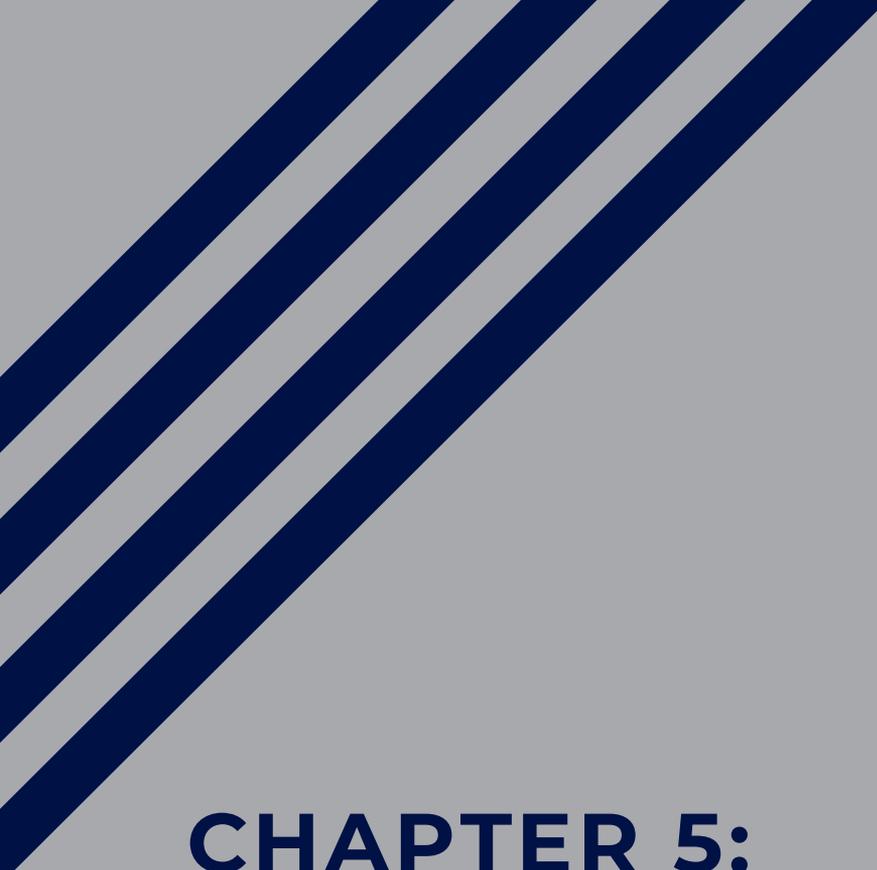
15. Which of the following statements best describes correction factors?

- a. Correction factors quoted by the manufacturer are valid throughout the life of the monitor
- b. Correction factors are determined through experiment
- c. Correction factors are only theoretical and have not been determined by experiment
- d. Correction factors are only accurate between 1 and 100% LEL

16. Which of the following statements is a correct interpretation of 20% LEL?

- a. Cold work with SCBA or SABA
- b. No entry due to fire danger
- c. Hot and cold work provided OEL not exceeded
- d. Emergency measures only

NOTES



CHAPTER 5:

Control Methods for High Combustible Gas Readings



OUTCOME

Explain control measures available to reduce personnel exposure to flammable substances.



OBJECTIVES

1. Identify methods used to control occupational hazards.
2. Identify hazards and apply appropriate controls to reduce or eliminate the risk of exposure to combustible gas/vapour.

INTRODUCTION

All workplace hazards (chemical, physical, etc.) can be controlled by a variety of methods. The goal of controlling hazards is to prevent workers from being exposed to occupational dangers. Some methods of hazard control are more efficient than others, but a combination of methods usually provides a safer workplace than relying on a single method. Some methods of control are more economical than others but may not provide the most effective way to reduce occupational hazards.

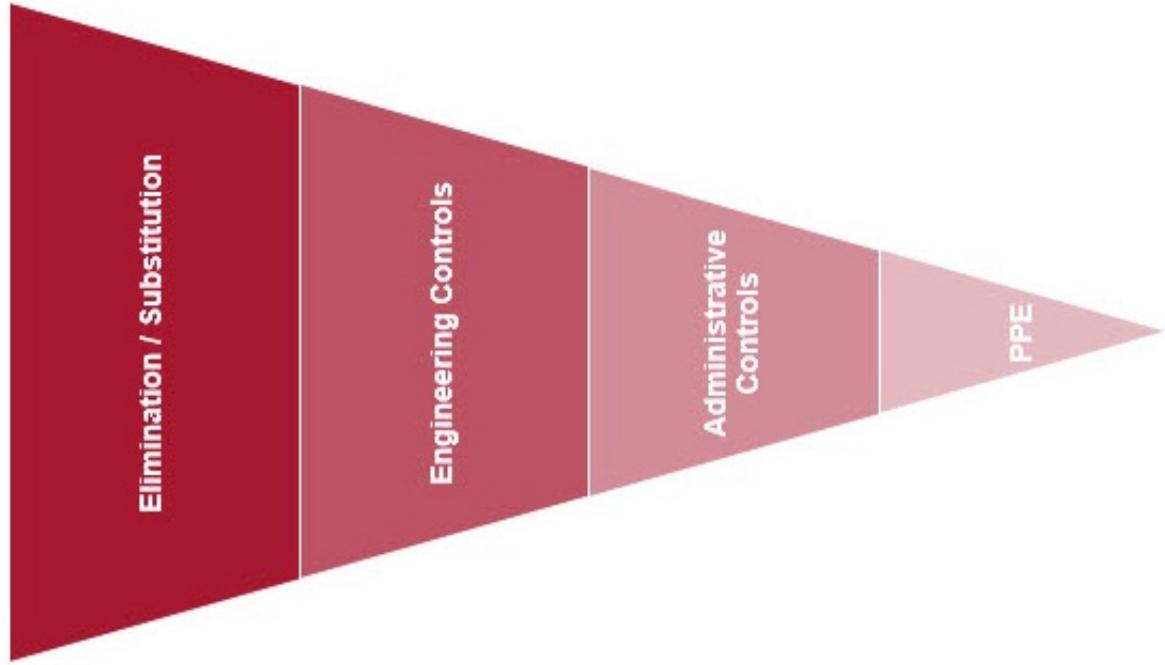
The most effective method of controlling hazards is to control at the source by eliminating the hazard or by substituting a hazardous agent or work process with a less dangerous one. Before thinking about what control measures are needed, however, first you must know whether there are health and safety problems in your workplace, and if so, what they are.

Once you recognize a hazard, then you can determine which measure will correct the problem most effectively. The major categories of control measures are:

- » Elimination/Substitution
- » Engineering Controls
- » Administrative Controls
- » Personal Protective Equipment

This chapter introduces the reader to control methods or options that can be implemented to reduce or eliminate the risk of exposure to a high combustible gas/vapour concentration.

STANDARD HIERARCHY OF CONTROLS



FEHM CONTROL PRIORITIES (WITH SOME EXAMPLES)



- *Design for minimum risk through “inherently safer” concept
 - » Eliminate flammable fluids
 - » Use a higher flash point material as a substitute for lower flash point material
 - » Increase distance
 - » Reduce corrosion rates through improved metal selection
- *Incorporate safety devices or protective safety design features
 - » Relief valves, automated emergency isolation valves, or automated depressurization / deinventory devices
 - » Active / passive fire protection
 - » Meeting electrical classification requirements
 - » Backflow prevention systems and blowout preventers
 - » Flare and disposal systems
- *Automated warning devices / signals (requiring manual intervention in response)
 - » Administrative controls & procedures
 - » Standard operating procedures
 - » Emergency operating procedures
 - » Start up / shut down procedures
 - » Access controls
- *Personal Protective Equipment
 - » Fire resistant coveralls / clothing / undergarments
 - » Safety glasses
 - » SCBA for egress

Figure 5-1
The Hierarchy of Controls

METHODS OF CONTROL

Elimination/ Substitution

Elimination of a specific hazard or hazardous work process, or preventing it from entering the workplace, is the most effective method of control. During this process, it is important to consider worker health and safety when work processes are still in the planning stages.

If a particularly flammable compound or work process cannot be completely eliminated, then try to replace it with a safer substitute. For example, the use of heavier frac oils rather than light condensates for well fracturing is preferred.

Engineering Controls

If a hazardous substance cannot be eliminated or substituted, then enclosing it so workers are not exposed to the hazard is the next best method of control. Many hazards can be controlled by partially or totally enclosing the work process. Highly toxic materials that could be released into the air should be totally enclosed.

Whole areas of a plant can be “enclosed” by requiring workers to operate those areas from a control room. Enclosing hazards can minimize possible exposures, but does not eliminate them. For example, maintenance workers who service or repair these “enclosed” areas can still be exposed. To prevent maintenance workers from being exposed, other protective measures (such as protective clothing, respirators, proper training, medical surveillance, etc.) must be used, as well as safety procedures.

Isolation can be an effective method of control through the use of lock-out/tag-out, blind flanges, double block and bleed, electrical lock out, or rendering equipment safe to work on or in a state of zero energy.

Provided below are a number of engineering control examples:

Reduce generation of the hazard and interrupt the pathway between the source and the receiver through isolation or enclosure of the worker or the process.

For example, use closed pressure rig tanks rather than open top tanks for well servicing or use pipelines for flammable and/or corrosive, toxic materials.

Install sensors for abnormal operation and devices for emergency shutdown. For example, use high/low temperature, level, pressure alarms or use flammable gas detection devices.

Purge tank and vessel. This involves removing the contents of a pipe or container and replacing it with another gas or liquid. A variety of substances can be used including water, steam, nitrogen, carbon dioxide, air, etc. Your company should have vessel specific purging procedures.

Ventilate tank or vessel mechanically. This can be used to purge a tank or vessel of flammable gases/ vapours prior to working inside the space in order to maintain a safe environment during work.

For example, intrinsically safe fans and venturi air movers are very effective means for removing gases from inside worksites and controlling the accumulation of gases generated from sludge and tank residue.

Use blocks or barricades to prevent worker contact. For example, blocking pump jack weights from moving.

Administrative Controls

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

Procedures

- » Develop and evaluate safe work procedures. For example, develop specific work procedures for critical tasks (vessel entry, hot work, etc.). Then evaluate or audit the worker’s performance.
- » Use specific procedures to control emissions. For example, use piping systems rather than open pail transfer of product.
- » Limit the time duration of worker exposure to prevent the onset of boredom. For example, use job rotation and scheduled rest breaks. This also helps to maintain worker efficiency.

- » Select workers for specific tasks. Consider physical requirements, size, worker abilities, limitations, past work history and medical evaluation for such things as back problems and/or cardio-pulmonary function.

Training

Use qualified/trained watchmen for critical tasks such as confined space entry and Hot Tapping. For example, ensure workers are competent in the use of breathing apparatus.

Provide proper supervisory and worker training. Examples of training would include gas monitoring, emergency response and on the job training.

Maintenance/Inspections

A good preventative maintenance program and regular inspections will help ensure that facilities and equipment meet regulatory requirements and standards. This would include conducting proper bump tests and having a calibration program for monitors.

Personal Protection Equipment

Personal protective equipment (PPE) is the least effective method of controlling occupational hazards and should be used only when other methods cannot control hazards sufficiently. Note however that in some situations the only recourse available to provide adequate protection for the worker is the use of PPE. The PPE discussed in this section is limited to Fire Retardant Workwear (FRW) and specific Respiratory Protective Equipment. A complete program is required in industry to ensure correct selection, use and maintenance of all personal protective equipment.

Fire Retardant Workwear

Workers involved on worksites or in operations that have been classified as having a fire and explosion hazard will be required to wear fire retardant workwear (FRW).

FRW is made up of material that is inherently non-flammable and does not melt when exposed to heat and does not cause a build-up of static electricity. There are two types of fire retardant workwear available to industry:

1. Clothing constructed from flame retardant cloth and thread (e.g. Nomex)
2. Clothing that is coated with flame retardant material (e.g. Proban)

Other considerations for the selection of FRW include hardhat liners and gloves. Nylon and polyester clothing are not acceptable as inner or outer clothing on worksites where flammable substances are present.

Respiratory Protective Equipment

The only respiratory protective equipment acceptable by CAPP for protection against exposure to hydrocarbon gases and vapours above 10% LEL is:

- » Positive Pressure Self-Contained Breathing Apparatus (SCBA); and
- » Positive Pressure Supplied Air Breathing Apparatus (SABA).

SCBA and **SABA** are required in the following situations:

- » When the oxygen content in the air is less than 19.5%.
- » Where the atmospheric contaminants are considered to be immediately dangerous to life and health (IDLH), or above the OEL.
- » Where the concentration of the atmospheric contaminants or the actual contaminants are unknown.

Occupational Health and Safety Legislation requires an employer to establish a code of practice governing the selection, maintenance and use of respiratory protective equipment.

NOTE: Only fit-tested competent personnel who are physically able and are trained in the use of the required respiratory protection should be allowed to enter a contaminated or potentially contaminated area.

Right to Refuse Unsafe Work

All workers have the right to refuse unsafe work where they believe that an imminent danger exists to them or other workers. Imminent danger is a danger, which is not normal for the occupation or where a worker would not normally carry out this type of work. After the worker's refusal (with reason(s) provided to the supervisor), the employer must:

- » Investigate the work refusal and associate hazard;
- » Take corrective action; and
- » Prepare a report and supply the worker with a copy of the report.

Imminent danger is a danger which is not normal for the occupation or where a worker would not normally carry out this type of work.

STUDENT SCENARIOS

Drilling Rig Operations

Scenario #1 - Mud Tank Fire

Directions

Read the following situation and provide a list of 4-5 measures that could have prevented this situation from happening.

Situation

A drilling crew used crude oil for drilling fluid. The well was displaced with oil after running and cementing intermediate casing to a depth of 814 meters. The daylight crew was running a directional survey while circulating at a depth of 1038 meters. A loud bang was heard and fire was seen at the shaker tank. The fire quickly spread from the shaker compartment to the entire mud tank area. The Driller sounded the alarm and hit the engine shut-offs, then closed in the well. Workers were unable to extinguish the fire with site extinguishers. The water truck (full load on) was positioned by the back of the mud tank. A 3x2 inch swedge was placed into the discharge hose of the water truck. The truck was then used to pump water onto the flames. The crew was able to extinguish the flames from the ground.

Preventative Measures

1. _____
2. _____
3. _____
4. _____
5. _____

Well Servicing Rig Operations

Scenario #2 - Circulating With Rig Pump and Tank

Directions

Read the following situation and provide a list of 4-5 measures that could have prevented this situation from happening.

Situation

Rig crew finished pulling rods and bottom hold pump (bhp). The tubing needed to be de-waxed with wireline prior to re-running bhp and rods.

The well was circulated dead with crude oil prior to running wireline tools for de-waxing. After 30 minutes of pumping, the well kicked and released a large volume of gas. Upon seeing the vapours, the crew shut down the rig.

The crew waited 15 minutes for gas vapours to dissipate. When no physical signs of gas were present, the derrickman was instructed to start the rig pump and resume circulating. Upon starting the rig pump, a flash fire erupted. The derrickman was severely burnt. The rig tank and ground vegetation in front of rig pump caught fire.

The derrickman survived his burns but was unable to resume work.

Preventative Measures

1. _____
2. _____
3. _____
4. _____
5. _____

Confined Space

Scenario #3 - Applying Waterproof Coating

Directions

Read the following situation and provide a list of 4-5 measures that could have prevented this situation from happening.

Situation

One worker died and a second worker was severely injured in an explosion and fire inside a confined space. The first worker was inside a water cistern applying a flammable, waterproof coating using a truck-mounted spray system. The only access into the tank was through a vent opening at the top. The second worker was near the vent opening when the explosion occurred, knocking him off the roof. He suffered third-degree burns to his face, ears and hands. The worker inside the cistern suffered third-degree burns to 80% of his body and later died.

Preventative Measures

1. _____
2. _____
3. _____
4. _____
5. _____

Production

Scenario #4 - Service Rig Tank Flash Fire

Directions

Read the following situation and provide a list of 4-5 measures that could have prevented this situation from happening.

Situation

A crew was conducting well kill operations on a sweet oil well. A worker was monitoring the return flow to the service rig trough from on top of the rig tank. When the returns became gassier, the return flow was opened to the degasser section of the rig tank and the trough flow was pinched in slightly. The rig manager proceeded to the top of the rig tank stairs where his personal gas monitor immediately began to alarm on high LEL (lower explosive limit). The rig manager looked up to observe both the rig tank and the worker on the rig tank being engulfed in flames.

The worker standing on top of the rig tank jumped over the handrail to the ground, and suffered a broken hand from the landing. The flash fire resulted in minor burns to the worker's face, chest, back and thighs, and extensive burns to the forearms which required skin grafting surgery and 18 days in the hospital. The rig manager jumped off the stairs and was not injured in the event.

Preventative Measures

1. _____
2. _____
3. _____
4. _____
5. _____

SELF-EVALUATION / REVIEW

The following is a self-evaluation exercise aimed at testing your understanding of the material presented in this chapter. This exercise should take approximately 10 minutes to complete. You should not look back on the information in this chapter nor should you look at the answer key provided. You should be able to answer all of the questions correctly. You should review all the questions you have wrong by reading that part of the chapter again and/or discussing the question(s) you had wrong with your instructor prior to moving onto the next chapter.

1. Give an example of each control method as they relate to flammable substances.

Elimination	
Substitution	
Engineering	
Administrative	
PPE	

2. Define and give an example of imminent danger.

3. If you believe that an imminent danger exists, what should you do? What should your employer do?



APPENDICES

APPENDIX A: GLOSSARY OF TERMS

Active filament

The catalyst-treated filament in a catalytic combustible gas monitor, which is exposed to the gas concentration being measured. Also see reference filament.

Asphaltenes

Molecular substances found in crude oil, along with resins, aromatic hydrocarbons, and alkanes (i.e., saturated hydrocarbons). Asphaltenes consist primarily of carbon, hydrogen, nitrogen, oxygen, and sulfur, as well as trace amounts of vanadium and nickel. They form deposits on production equipment.

Asphyxiant

A gas or vapour that reduces or displaces the normal oxygen concentration in breathing air. Prolonged breathing of oxygen-depleted air can lead to death by asphyxiation (suffocation).

Auto-ignition temperature

The lowest temperature at which a mixture of combustible gas or vapour in air will spontaneously ignite in a normal atmosphere without an external source of ignition (e.g., flame or spark).

Benzene (C₆H₆)

An organic chemical compound consisting of six carbon and six hydrogen atoms, that is a natural constituent of crude oil, and one of the most basic petrochemicals. Benzene is a colorless, flammable liquid with a sweet odour. It evaporates quickly when exposed to air. Benzene is a cancer-causing compound.

BLEVE (Boiling Liquid Expanding Vapour Explosion)

An explosion caused by the rupture of a vessel containing a pressurized liquid above its boiling point. Hazards include blast wave, projectiles and, if flammable, a fireball and thermal radiation. Also see *high vapour pressure*.

Bump Test

see *function test*

Butane (C₄H₁₀)

A light hydrocarbon gas containing four carbon atoms and ten hydrogen atoms. When blended with propane and other hydrocarbons, it is referred to commercially as LPG or liquefied petroleum gas. Butane is a highly flammable, colourless and easily liquefied gas. It is used as a fuel, refrigerant, propellant in aerosols, and in the manufacture of petrochemicals.

Calibration test

A procedure in which an instrument, tool, or device is tested to confirm that it conforms with the standard. Calibration is very important, as it ensures the equipment is working properly. If the instrument fails a calibration test, minor repairs may be required to correct the problem.

Catalytic combustion detection

The detection of combustible gases by burning them on an active filament. The rise in resistance of the active filament, relative to that of a reference filament, determines the concentration of the gas.

Ceiling OEL

see *Occupational Exposure Limits (OELs)*

Confined space

A term from labour-safety regulations that refers to a dangerous area characterized by enclosed conditions and limited access.

Correction factor

The amount of deviation in a measurement that is accounted for in the calibration process. One can either multiply the correction factor by the measured value or adjust/calibrate the measuring instrument (e.g., zero adjustment).

ETHANE (C₂H₆)

A chemical compound with two carbon atoms and six hydrogen atoms. At standard temperature and pressure, ethane is a colourless and odourless gas.

Exothermic

Relating to a chemical reaction that produces heat

Explosive range

The ignition of a combustible vapour mixed with air in the proper proportions will produce flames and/or an explosion. This proper proportion is called the explosive range. The lowest percentage at which flames or explosions occur is the lower explosive limit (LEL), and the highest percentage is the upper explosive limit (UEL). Explosive limits are expressed in percent by volume of vapour in air and, unless otherwise specified, under normal conditions of temperature and pressure.

Flame arrestor

A sintered metal wafer-like structure through which gas flows before contacting the sensor of a catalytic combustible gas monitor. Its primary purpose is to dissipate heat generated by burning combustible gases in the sensor to below the ignition temperature of ambient gases. It also protects the sensor from mishandling and the cooling effects of wind.

Flash point

The lowest temperature at which materials can vaporize to form an ignitable mixture in air. Flash point refers to both flammable liquids and combustible liquids.

Function test

A field test carried out to determine if an instrument is in proper working order. The only way to confirm that a gas detector is functioning and is capable of responding to gas is to expose the instrument to a concentration of target gas high enough to initiate an alarm situation while the instrument is in operating mode. Also known as a “bump check”.

Gas

The state of matter distinguished from the solid and liquid states by relatively low density and viscosity, relatively great expansion and contraction with changes in pressure and temperature, the ability to diffuse readily, and the spontaneous tendency to become distributed uniformly throughout any container.

Hazardous locations

Areas with an atmosphere subject to hazardous concentrations of flammable gases or vapours or combustible dusts, fibres and flyings, as specified by the **Canadian Electrical Code, Part 1**. They are deemed hazardous because they are easily ignited by hot surfaces, open flames or sparks from electrical switches, motors and relays.

Hazardous areas are divided into three Classes:

1. May contain hazardous concentrations of flammable liquids, gases or vapours
2. May contain hazardous concentrations of combustible dusts
3. May contain ignitable fibres and flyings

Each class is divided into two Divisions:

1. Ignitable gas or vapour concentrations are likely to be present under **normal** operating conditions, may be present due to equipment repair, maintenance and leakage, or might be released by equipment failure at the time of an electrical equipment failure.
2. Flammable liquids or gases in closed systems are likely to escape under **abnormal** conditions, area is adjacent to Division 1 locations from which ignitable concentrations of gases or vapours might be conveyed, or accumulations of gases and vapours are usually prevented by mechanical ventilation, but could become hazardous if the ventilation system failed.

Gaseous materials are also grouped into one of four Groups:

- a. Atmospheres contain acetylene.
- b. Atmospheres include butadiene, ethylene oxide, hydrogen or other gases or vapours equivalent in hazard to hydrogen and propylene.
- c. Atmospheres contain acetaldehyde, cyclopropane, diethyl ether or ethylene.
- d. Atmospheres contain butane, gasoline, natural gas, propane and other gases or vapours of equivalent hazard.

Hexane (C₆H₁₄)

A hydrocarbon gas, containing six carbon atoms and 14 hydrogen atoms. Hexanes are significant constituents of gasoline. They are colorless liquids at room temperature, with boiling points between 50 and 70°C, with gasoline-like odour. They are widely used as cheap, relatively safe, largely unreactive, and easily evaporated non-polar solvents.

Heptane (C₇H₁₆)

A hydrocarbon gas, containing seven carbon atoms and 16 hydrogen atoms. A component of raw hydrocarbon production used as a solvent and in the manufacture of petrochemicals.

High Vapour Pressure (HVP) liquids

Liquefied gases, which have a vapour pressure greater than 240 kPa at 38EC (34.8 psig @ 100 EF), including ethane, propane and butane. Also see *BLEVE*.

Hot Work

Work involving the use of flame or that presents the possibility of producing sparks. This includes the use of non-classified electrical equipment, internal combustion engines and other work such as cutting, welding, burning, air gouging, rivetting, drilling, grinding or chipping.

Hydrocarbon

An organic compound consisting entirely of hydrogen and carbon (e.g., heptane, butane, propane). The majority of hydrocarbons found naturally occur in crude oil, where decomposed organic matter provides an abundance of carbon and hydrogen.

Inerting

The process of converting from flammable or reactive conditions into a safe non-flammable state by the addition of an inert fluid - usually nitrogen.

Infrared detection

The detection and measurement of a gas by passing an infrared beam through the gas. The difference in absorption of light, compared to an unaffected beam, indicates the gas concentration.

Intrinsically-safe

A condition under which sparks or thermal effects occurring in normal use or under probable fault conditions are incapable of igniting prescribed flammable gases, vapours or dusts.

Light hydrocarbon gas

Any of the lower molecular weight hydrocarbon gases, such as methane, ethane, propane or butane.

Liquefied Petroleum Gas (LPG)

Liquefied petroleum gas, also called LPG, GPL, LP Gas, liquid propane gas or simply propane, is a flammable mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles.

Lower Explosive Limit (LEL)

The lowest concentration (percentage) of a gas or a vapor in air capable of producing a flash of fire in presence of an ignition source (arc, flame, heat). At a concentration in air below the LEL there is not enough fuel to continue an explosion. Concentrations lower than the LEL are “too lean” to explode.

Methane (CH₄)

A light hydrocarbon gas, containing one carbon atom and four hydrogen atoms. It is the main component of natural gas, and probably the most abundant organic compound on earth. The relative abundance of methane makes it an attractive fuel. However, because it is a gas at normal conditions, methane is difficult to transport from its source.

Narcosis

A state of impairment of the central nervous system affecting physical, psychological and physiological abilities caused by the effects of certain chemical substances, including hydrocarbon products. Symptoms include disorientation, slower judgment and decision-making, temporary loss of memory, headaches, slurred speech, dizziness and an unsteady gait.

Natural gas

Natural gas is a naturally occurring hydrocarbon gas mixture consisting primarily of methane, with up to 20 percent concentration of other hydrocarbons as well as impurities in varying amounts such as carbon dioxide. In addition to serving as an energy source, natural gas is also a feedstock in the manufacture of products such as fertilizers.

Occupational Exposure Limits (OELs)

The maximum concentrations of specified airborne substances to which workers may be exposed to in Alberta. OELs may be for time-weighted average (TWA) periods of 8 hours or short-term exposure limits (STEL) of 15 minutes, or may be absolute (Ceiling) exposure limits, which may not be exceeded at any time. These exposure limits may be expressed differently in other jurisdictions (i.e. *Workplace Contamination Limits* in Saskatchewan).

Passive sampling system

A sampling system where combustible gas sensors are directly exposed to the atmosphere and does not require active air movement from a pump. Airborne gases and vapours are collected through a physical process, such as diffusion through a static air layer or permeation through a membrane.

Pegging (or over-ranging)

A common response of catalytic combustible gas monitors where a high hydrocarbon gas concentration causes a rapid rise and fall to zero reading. If the monitor display is not watched continuously, the zero reading may mistakenly be interpreted as meaning no gas or vapour is present.

Pellistor-type sensor

A catalytic combustible gas sensor with active and reference filaments composed of a platinum wire encapsulated in a ceramic bead with a catalyst deposit. Both filaments are identical, except that the reference filament is rendered inactive by poisoning or encapsulating of the catalyst. Unlike the sniffer-type sensor, both filaments are exposed to the gas stream.

Pentane (C₅H₁₂)

A hydrocarbon containing five carbon atoms and twelve hydrogen atoms. A component of raw hydrocarbon production used in fuels and the manufacture of petrochemicals.

Percent Lower Explosive Limit (% LEL)

The lower explosive limit (LEL) of a combustible gas is the smallest amount of the gas that supports a self-propagating flame when mixed with air and ignited. Zero percent LEL denotes a combustible gas-free atmosphere. One hundred percent lower explosive limit denotes an atmosphere in which gas is at its lower flammable limit.

Propane (C₃H₈)

A light hydrocarbon gas containing three carbon atoms and eight hydrogen atoms. A component of raw hydrocarbon production and liquefied petroleum gas (LPG) used as a fuel, refrigerant, propellant in aerosols and in the manufacture of petrochemicals.

Purging

The practice of removing the contents of a pipe or container (by displacement or dilution) and replacing it with another gas or liquid. In dilution purging, the concentration of the initial contents is reduced or eliminated through another gas or liquid with a considerable amount of mixing. In displacement purging, the initial contents are pushed out by the replacement gas or liquid (some mixing may still occur).

Reference filament

The filament in a catalytic combustible gas sensor that is rendered inactive and serves to compensate for changes in ambient temperature, pressure and the cooling effects of gas contacting the sensor. Also see *active filament*.

Sample draw system

A sampling system, which includes a motorized sample draw pump (or hand aspirator) and sampling hose used to draw the gas sample to the sensors. It is used in portable area monitors and for conducting fugitive emission surveys.

Semi-conductor detection

The detection of a combustible gas by exposing the semi-conductor surface of the sensor to the gas. This exposure changes the electrical conductivity of the sensor, indicating the concentration of the gas.

Sniffer-type sensor

A catalytic combustible gas sensor with identically constructed active and reference filaments composed of a platinum wire. Only the active filament is exposed to the gas stream. This type of sensor is commonly used in older hand-aspirated instruments and requires more power than pellistor-type sensor.

Span adjustment

A procedure used in calibrating a gas monitor in which the sensitivity of the monitor is adjusted when the sensor is exposed to a gas of known concentration.

Specific Gravity

Comparison of the weight of a liquid/solid to the weight of water. Values less than one (1) indicate a substance that is lighter than water.

Stable Environment

A Stable environment exists when the surrounding atmosphere is at a constant safe monitoring level.

Stenching

The practice of adding an odorous substance to odourless hydrocarbon gases to warn people of their presence.

Thermal conductivity detection

The detection of a gas by using the change in resistance of a heated filament.

Time-Weighted Average (TWA)

The average exposure to a contaminant or condition (such as noise) to which workers may be exposed without adverse effect over a period such as in an 8-hour day or 40-hour week.

Toluene (C₇H₈)

A hydrocarbon containing seven carbon atoms and eight hydrogen atoms. Component of raw hydrocarbon production and used as a solvent and in the manufacture of petrochemicals.

Upper Explosive Limit (UEL)

The point at which, due to insufficient oxygen present, the concentration of a gas in air becomes too great to allow an explosion upon ignition.

Vapour

A substance in the gaseous state that can be liquefied (condensed) by high pressure or chilling.

Vapour density

Comparison of the weight of a gas/vapour to the weight of air. Values less than one (1) indicate a substance that is lighter than air.

Vapour pressure

The pressure exerted by the vapour of a substance when the substance and its vapour are in thermodynamic equilibrium. All liquids have a tendency to evaporate, and some solids can sublimate into a gaseous form. Vice versa, all gases have a tendency to condense back to their liquid form, or deposit back to solid form, as long as the temperature is below their critical temperature or decomposition temperature.

Xylene (C₈H₁₀)

A hydrocarbon containing eight carbon atoms and ten hydrogen atoms. A component of raw hydrocarbon production used as a solvent and in the manufacture of petrochemicals.

Zero adjustment

A procedure used in calibrating a gas monitor using contaminant-free air as the test gas.

APPENDIX B: USE OF COMBUSTIBLE GAS METERS

Combustible gas meters are frequently used at Alberta work sites to evaluate and assess fire and explosion hazards. It is critical that this equipment be properly used and calibrated so that these hazards are not underestimated. The instruments can be a valuable tool if used by operators who are well informed of their limitations.

It is common practice to use meters to measure for a variety of gases. Errors result when meters calibrated on a specific gas are used to measure other explosive gases or vapours. In one case investigated by Alberta Employment and Immigration, a methane calibrated meter was used to measure gasoline vapours; the meter gave a reading of 14% LEL (Lower Explosive Limit) while the actual concentration in the tank was 73% of the LEL.

Most combustible gas detectors measure the contaminant by combustion at a catalytic detector. The heat produced is used as a measure of the explosive nature of the contaminant in air. Different compounds produce different amounts of heat when they are burned. So the meters respond differently to different chemical mixtures in air. Table 1 compares the actual percent LEL of four different compounds required to produce a meter reading of 20% for a typical combustible gas meter. There are wide variations in meter response as the compound and its heat of combustion vary.

Combustible gas meters can only be expected to respond accurately to the gas for which they were calibrated. To measure other gases with the same meter, consideration must be given to the specific properties of the gas and of the detector. Some manufacturers have responded to the need to estimate more accurately the concentration of other gases by providing correction factors, which allow calculation of percent LEL from the measured level. A guide to their use is provided in Appendix A. Even when these factors are used, interpretation of the reading must be made by someone who has training and experience to understand how different factors may affect results.

Table C-1 Variation in Meter Response with Chemical Compound & Heat of Combustion

COMPOUND	VAPOUR CONCENTRATION REQUIRED TO PRODUCE A 20% LEL METER RESPONSE (% LEL)	HEAT OF COMBUSTION KCAL/MOL
Ammonia	15.8	107
Methane	20.0	213
n-Hexane	54.2	995
Biphenyl	80.0	1494

Combustible gas meters cannot be relied upon to:

1. Accurately measure highly toxic gases such as hydrogen sulphide.
2. Respond accurately in atmospheres, which do not contain 20.9% oxygen in air.
3. Provide a reliable indication of the degree of explosive hazard when meters are not calibrated before and after each use.
4. Compensate for poor field sampling technique or an operator failure to consider the conditions of the work environment (for example temperature).

For highly toxic gases the danger to health is usually of much greater concern than their explosive nature. For example, hydrogen sulphide has an IDLH (immediately dangerous to life and health) level of 100 ppm, while its LEL is 43,000 ppm. A meter designed to measure a compound’s explosive nature cannot be expected to have the sensitivity required to evaluate the hazard to health.

Oxygen concentrations in air, lower than those normally occurring in the atmosphere (20.9%), may result in underestimating an explosive hazard. The response of the meter depends on its ability to burn the combustible gas. If there is not enough oxygen to support combustion, the meter will read a lower or even 0% LEL, even if high levels of combustible gas are present. Since it is common for

meter sensors to fail, calibration, or function testing, is required to ensure that a hazardous atmosphere is properly detected. Furthermore, when the sensor is exposed to moisture, lead compounds, silicon compounds, or chlorinated hydrocarbons, it may fail. Drift may also occur if the instrument is not allowed to acclimate to the environment in which it will be used, (for example an instrument is used outdoors during the winter). Calibration after the measurement has been taken is also used to validate instrument function. Combustible gas meters must only be used by those people who are competent in their use. Training should be based on a comprehensive guide of practice such as:

**Manual of Recommended Practice for Combustible Gas Indicators and Portable, Direct Reading Hydrocarbon Detector
American Industrial Hygiene Association
475 Wolf Ledges Parkway
Akron, Ohio 443311**

In addition, the manufacturer’s operating manual or technical representative should be consulted to supply more detailed information on a particular combustible gas meter.

SELF-EVALUATION TEST ANSWERS

Chapter 1

SELF-EVALUATION TEST			
1.	c	6.	d
2.	a	7.	a
3.	Stenching/ Odorizing	8.	d
4.	c	9.	a
5.	d	10.	b
		11.	d

Chapter 2

SELF-EVALUATION TEST			
1.	d	6.	d
2.	a	7.	b
3.	c	8.	a
4.	b	9.	c
5.	b	10.	d

Chapter 3

SELF-EVALUATION TEST	
1.	b
2.	a
3.	c
4.	b
5.	1 – Check Record Log 2 – Prepare Detector 3 – Zero Detector 4 – Check Detector Response 5 – Record Function/Bump Test

Chapter 4

SELF-EVALUATION TEST			
1.	c	9.	a
2.	a	10.	a
3.	c	11.	c
4.	d	12.	c
5.	c	13.	c
6.	b	14.	a
7.	c	15.	c
8.	c	16.	d

Chapter 5

SELF-EVALUATION TEST	
1.	Answers will vary
2.	Imminent danger is a danger which is not normal for the occupation or where a worker would not normally carry out this type of work. Examples will vary.
3.	You have the obligation to refuse unsafe work. Your employer must investigate, take corrective action and prepare a report

LIFE SAVING RULES



CONFINED SPACE

Obtain authorization before entering a confined space

- I confirm energy sources are isolated
- I confirm the atmosphere has been tested and is monitored
- I check and use my breathing apparatus when required
- I confirm there is an attendant standing by
- I confirm a rescue plan is in place
- I obtain authorization to enter



WORKING AT HEIGHT

Protect yourself against a fall when working at height

- I inspect my fall protection equipment before use
- I secure tools and work materials to prevent dropped objects
- I tie off 100% to approved anchor points while outside a protected area



WORK AUTHORIZATION

Work with a valid permit when required

- I have confirmed if a permit is required
- I am authorized to perform the work
- I understand the permit
- I have confirmed that hazards are controlled and it is safe to start
- I stop and reassess if conditions change



ENERGY ISOLATION

Verify isolation and zero energy before work begins

- I have identified all energy sources
- I confirm that hazardous energy sources have been isolated, locked, and tagged
- I have checked there is zero energy and tested for residual or stored energy



LINE OF FIRE

Keep yourself and others out of the line of fire

- I position myself to avoid:
 - Moving objects
 - Vehicles
 - Pressure releases
 - Dropped objects
- I establish and obey barriers and exclusion zones
- I take action to secure loose objects and report potential dropped objects



BYPASSING SAFETY CONTROLS

Obtain authorization before overriding or disabling safety controls

- I understand and use safety-critical equipment and procedures which apply to my task
- I obtain authorization before:
 - Disabling or overriding safety equipment
 - Deviating from procedures
 - Crossing a barrier



DRIVING

Follow safe driving rules

- I always wear a seatbelt
- I do not exceed the speed limit, and reduce my speed for road conditions
- I do not use phones or operate devices while driving
- I am fit, rested and fully alert while driving
- I follow journey management requirements



HOT WORK

Control flammables and ignition sources

- I identify and control ignition sources
- Before starting any hot work:
 - I confirm flammable material has been removed or isolated
 - I obtain authorization
- Before starting hot work in a hazardous area I confirm:
 - A gas test has been completed
 - Gas will be monitored continually



SAFE MECHANICAL LIFTING

Plan lifting operations and control the area

- I confirm that the equipment and load have been inspected and are fit for purpose
- I only operate equipment that I am qualified to use
- I establish and obey barriers and exclusion zones
- I never walk under a suspended load



FIT FOR DUTY

Be in a state to perform work safely

- I will be physically and mentally in a state to perform my assigned duties
- I commit to not being under the influence of alcohol or drugs
- I will inform a supervisor immediately if I or a co-worker may be unfit for work

customerservice@energysafetycanada.com
1 800 667 5557

EnergySafetyCanada.com