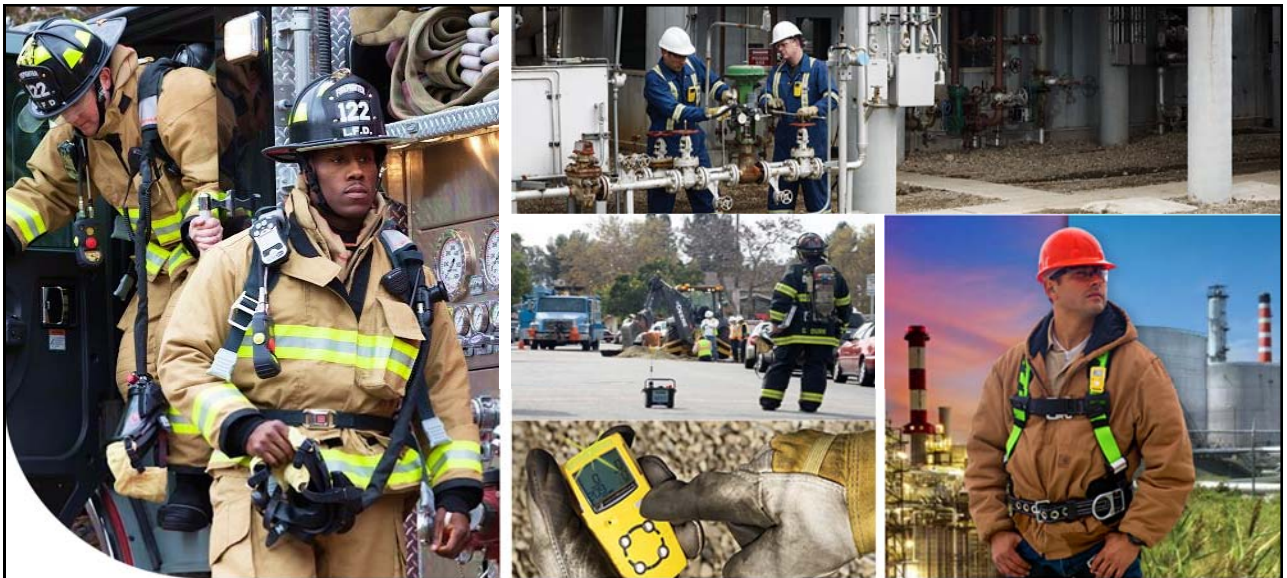

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CONNECTED WORKER

Portable Gas Detection Sensor Technologies

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S.P.A.C.E.R.

Safety

Site regulations; identify emergency exits; washrooms; escort required badge; smoking policy; when working with calibration gas cylinders it is important to lay the cylinders down to avoid accidents.

Purpose

Improve your knowledge of portable safety gas detectors and sensor technology; increase your product service capability; and, provide a service certificate for the BW product line.

Agenda

Discuss the core sensor technologies, provide hands on operations, maintenance, bump testing and calibration experience.

Code of Conduct

Please have phones on vibrate or off, breaks will be provided throughout the session. Recording or taping training session is not permitted.

Expectations

Be on time; learn something new.

Roles

Participate and ask questions.

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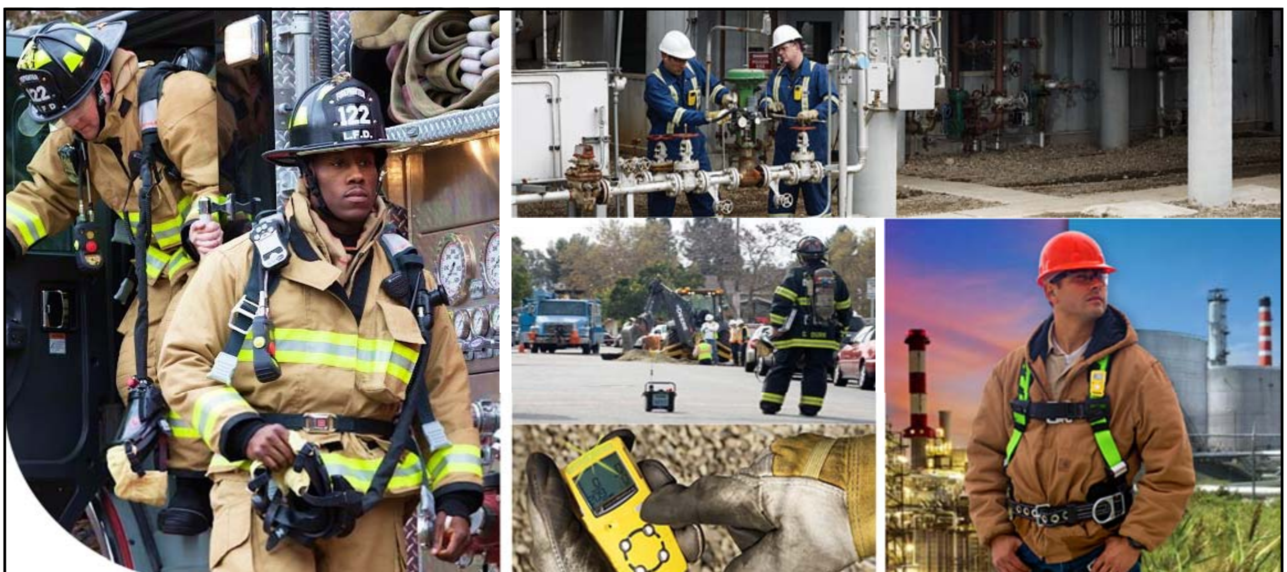
Common Gas Detection Acronyms

LEL/LFL	Lower Explosive Limit/ Lower Flammable Limit (synonymous)
UEL/UFL	Upper Explosive Limit/Upper Flammable Limit (synonymous)
%LEL	Percent of the Lower Explosive Limit
% v/v	Percent by volume (also expressed as % VOL)
ppm	Parts Per Million (10,000 ppm = 1% v/v)
VOC	Volatile Organic Compounds
PID	Photoionization Detection
TWA	Time Weighted Average
STEL	Short Term Exposure Limit
IDLH	Immediately Dangerous to Life and Health toxic gas concentration
IP	Ionization Potential
IP	Ingress Protection
IS rating	Intrinsic Safety Rating (device will not generate enough energy to be the source of ignition in a combustible atmosphere)
RFI/EMI	Radio Frequency Interference / Electro-Magnetic Field Interference
T90	Refers to sensor response time - time sensor takes to reach 90% of full response
LDL	Lowest Detectable Limit



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WHY WE DO WHAT WE DO

Portable Gas Detection Sensor Technologies

What is this Device?

Portable Safety Gas Detector

- Portable safety gas detectors are designed to detect and alarm workers to the presence of potentially life threatening ambient atmospheric gas hazards.
- Detects gas in the immediate atmosphere - target gas molecules diffuse into the sensor - the detector experiences what the person wearing the detector is experiencing.
- When using a sample draw system the readings will be representative of the atmosphere at the end of the sampling tubing

Types of Alarms

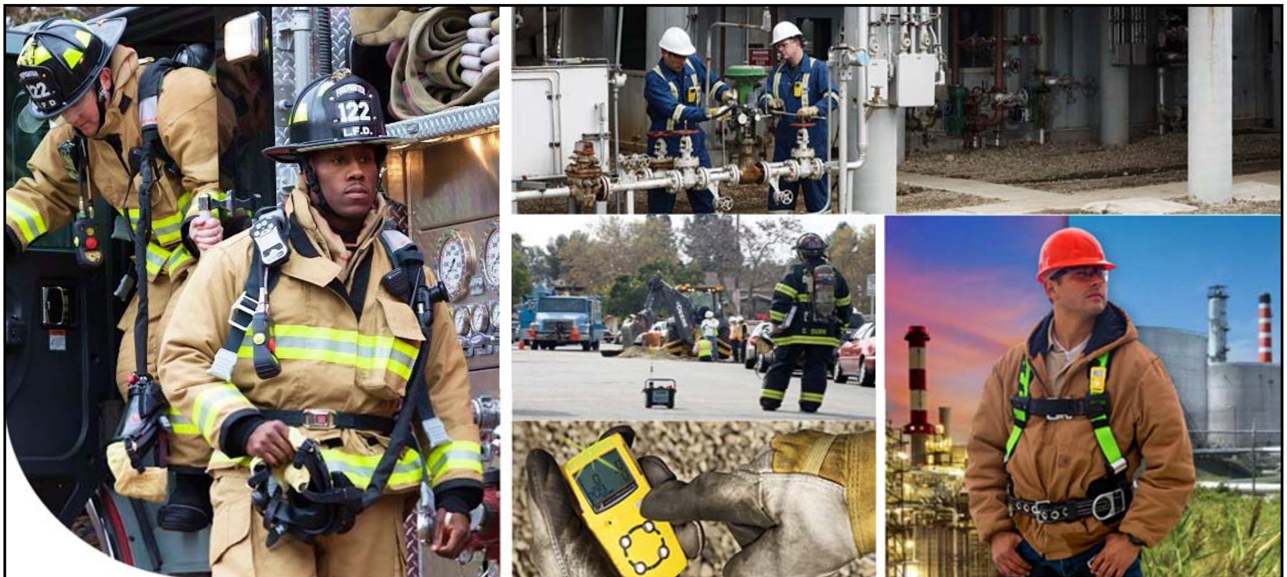
Alarm indication:
Visual red LED alarm bars
Audible alarm
Vibrating alarm

Type of Alarms:
Instantaneous gas exposure
STEL gas exposure
TWA gas exposure
Over Limit (OL) sensor alarm
Low Battery Warning

*** Remember: gas alarm set points are set very conservative to provide early warning so workers can take appropriate action.**

Why is Gas Detection Important?

- ✓ Protect Personnel
- ✓ Confirm an area is safe to occupy
- ✓ Gather Evidence
- ✓ Maintain Legal Compliance
- ✓ Protect Infrastructure
- ✓ Protect the Environment
- ✓ Control Processes / Gather Data
- ✓ Improve Productivity



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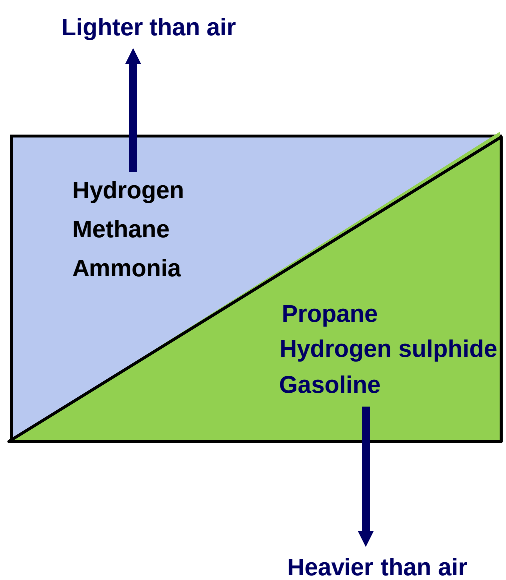
REMOTE SAMPLING

Portable Gas Detection Sensor Technologies

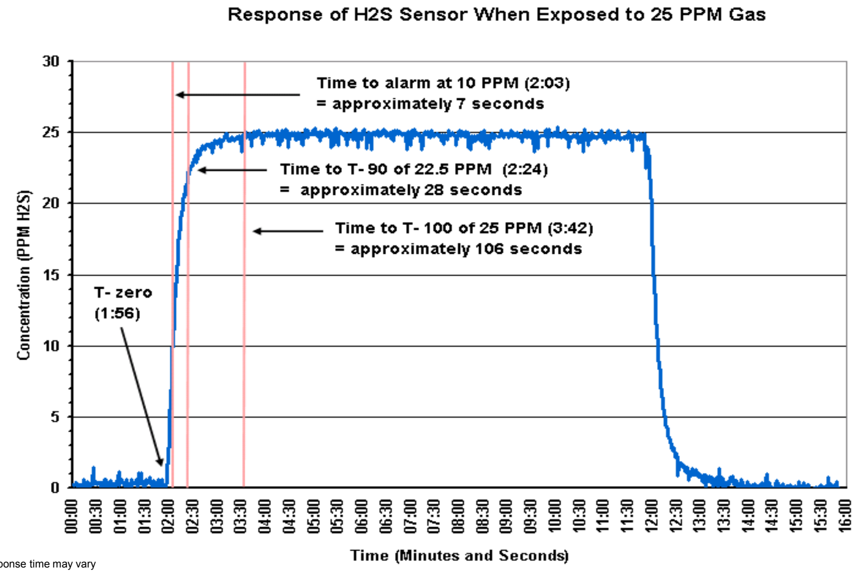
Understand the Hazards!

Gases are not ideal; they have different properties

- Molecular weight of air: 28.966
- Gases lighter than air tend to rise; gases heavier than air tend to sink
- Know as much as possible about the hazards you are dealing with



Consider Sensor Response Time



*actual sensor response time may vary

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Consider Sampling Lag Time

- It is essential to verify the integrity of the sampling train before use
- Always allow sufficient time for sample to reach sensors and then at least 60 seconds for readings to stabilize; or, continue sampling until readings stabilize.

Instrument	Max Tubing Length	Sec/foot or pumps/foot
GasAlertMax XT II	23 m/75 feet	2 sec
GasAlertMicro 5 Series – w/sample probe	20 m/66 feet	3 sec
GasAlertMicro 5 Series – w/particulate filter	3m/1 foot	3 sec
Manual Hand Aspirator Pump	3m/10 feet	1 squeeze/foot

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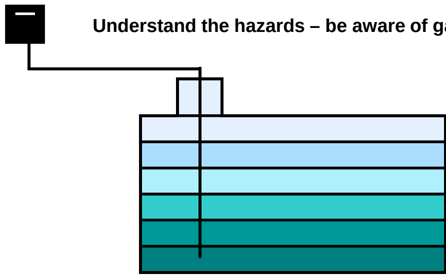
Confined Spaces are Dangerous Places!

Understand the hazards – be aware of gas stratification – do not underestimate the potential hazards!



- Atmospheric hazards in a confined space can be found at various levels
- **CHECK ALL LEVELS**! Atmosphere tested (at least) approximately every 4 feet (1.22 m) in the direction of travel and to each side
- Allow sufficient time for all sensors to react to each sample per level tested. Key response factors are hose length (typical 2 seconds per foot flow rate) plus T90 sensor(s) response time
- **Example:** 10 feet hose x 2 seconds = 20 seconds plus most significant T90 of monitor's sensors (approximately 30 seconds for standard 4 gas detector). (10 x 2) + 30 = 50 seconds per level minimum
- If any gas is present during sampling it is essential to continue testing until readings remain stable (T100 response)

Pre-entry Sampling

GasAlertMicro 5 Series

GasAlertMax XT II

Hand Aspirator Kit

Pre-entry Sampling the Wrong Way

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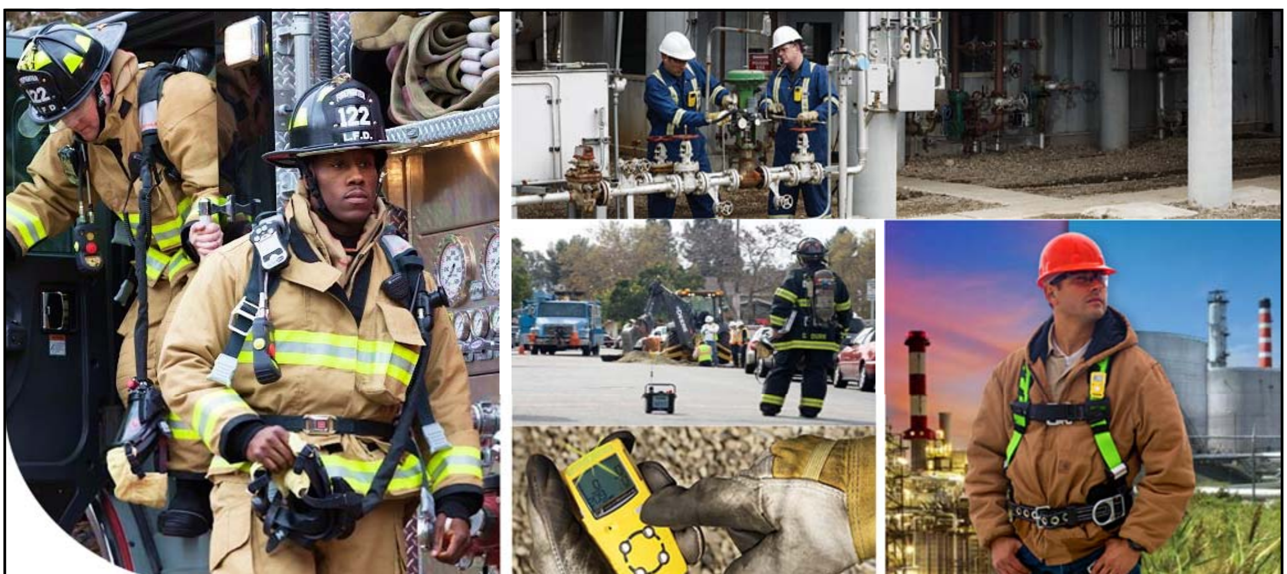

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AT THE HEART OF GAS DETECTION

Portable Gas Detection Sensor Technologies

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Sensing Technologies

At the heart of every gas detection measurement is a sensor - Honeywell Portable Safety Gas Detector Sensing Technologies

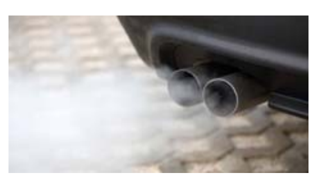
- Electrochemical - oxygen; toxic gases
- Catalytic bead – combustible gases
- Photoionization (PID) – toxic gases; VOCs
- Non-dispersive infrared (NDIR) – CO_2 ; combustible gases

CITY TECHNOLOGY
AT THE HEART OF
GAS DETECTION

What is Gas?

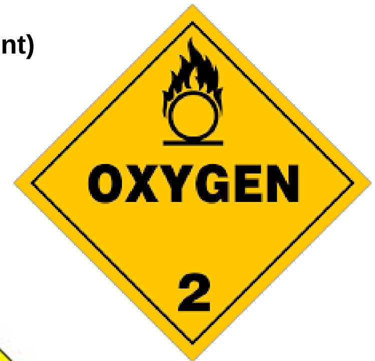
Gases are all around us

- The air we breathe is made up of several different gases including Nitrogen, Oxygen and Carbon Dioxide – simply put, gas is a state of matter – in Grade 2 science we begin to learn about the 3 states of matter – solid, liquid, **gas**
- Gases can be created naturally or through anthropogenic activity
- Gases are used everyday to cook, heat our homes, barbeque...
- Combustion produces carbon monoxide – decomposition of biological materials can produce gases such as hydrogen sulphide and methane
- A vapour is a gas that previously existed in either a solid, or liquid state of matter



Gas Hazards

- Oxygen (deficiency and enrichment)
- Flammable gases and vapors
- Toxic contaminants

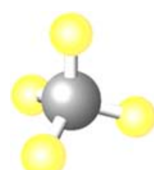


Some Common Gas Hazards

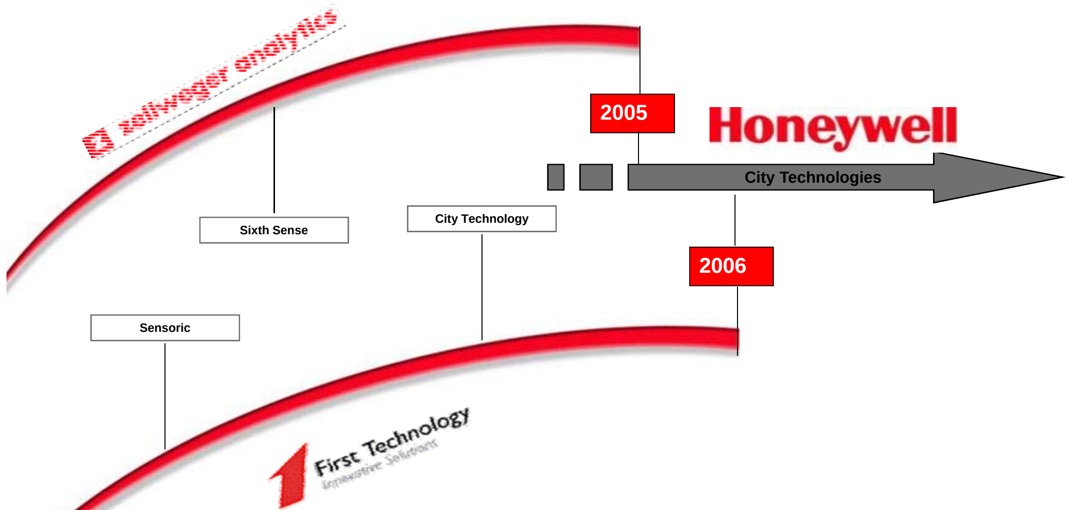
A gas detectors job is to detect changes in oxygen concentration, and the presence of toxic and combustible gas phase hazards that present potentially life threatening atmospheric conditions.

- **Oxygen (O_2)**
- **Combustible gases (LEL)**
- **Carbon monoxide (CO)**
- **Hydrogen sulphide (H_2S)**

- Ammonia (NH_3)
- Carbon dioxide (CO_2)
- Chlorine (Cl_2)
- Chlorine dioxide (ClO_2)
- Ethylene oxide (ETO)
- Hydrogen cyanide (HCN)
- Nitric oxide (NO)
- Nitrogen dioxide (NO_2)
- Ozone (O_3)
- Phosphine (PH_3)
- Sulphur dioxide (SO_2)
- Volatile organic compounds (VOCs)

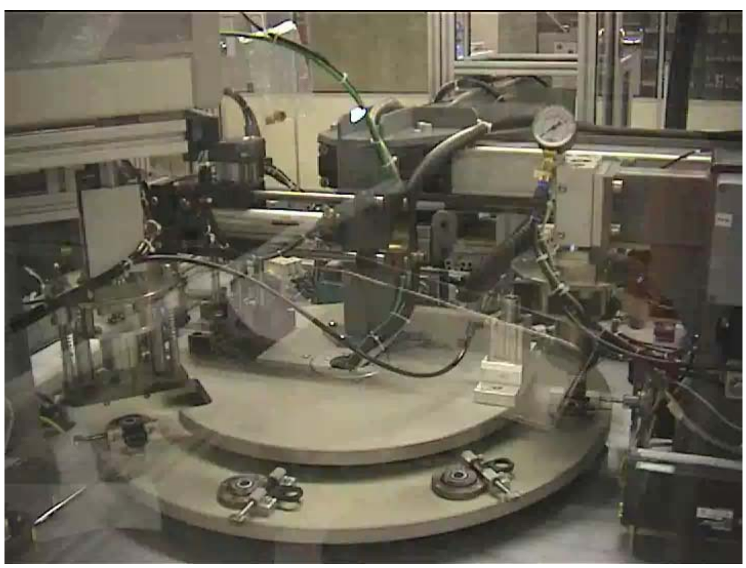


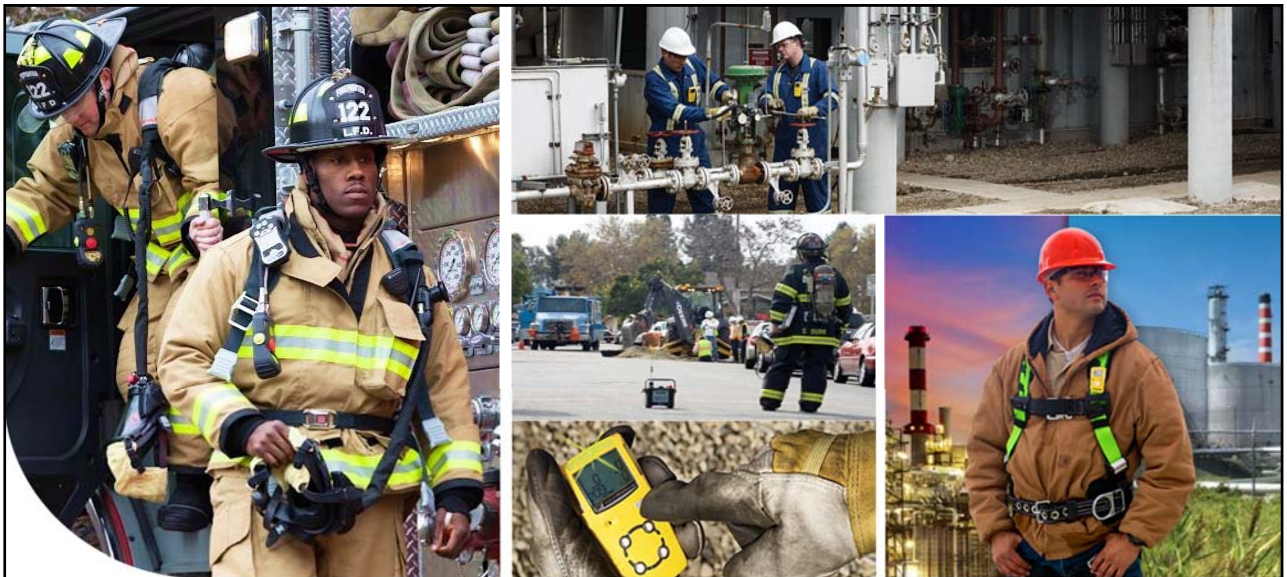
Gas Detection Sensor Manufacturing



Electrochemical Sensor Manufacturing

- Honeywell designs and manufactures most of the sensing technologies used in our gas detectors
- World's largest gas sensor manufacturer
- Advanced robotic manufacturing provides production and quality consistency
- ISO manufacturing traceability





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OXYGEN

Not enough? Too much? How do I know?

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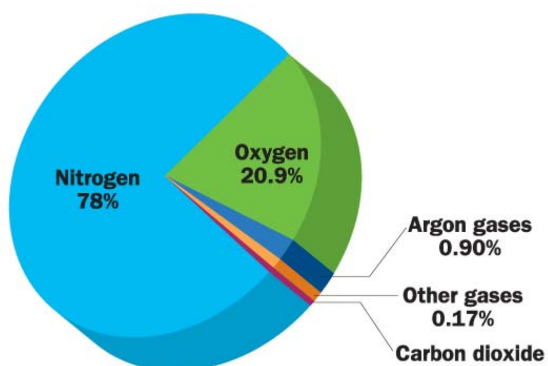
A Breath of Fresh Air

Average molecular weight of dry air is 28.97g/mol

Composition (Mole percent):

N_2	78.084
O_2	20.947
Ar	0.934
CO_2	0.0400
Ne	0.001818
He	0.000524
CH_4	0.00017
Kr	0.000114
H_2	0.000053

Other trace gases include:
O_3, CO, Xe, SO_2, NO_2, NH_3



Portable safety gas detector reading in "fresh air":
20.9% v/v – oxygen
0 ppm – toxic gases
0% LEL – combustible gases

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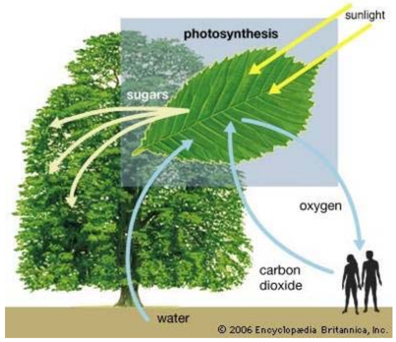
Oxygen Hazards

Oxygen measurement to warn of changes in oxygen concentration from 20.9% v/v



Depletion:

- Oxygen supports life
- Concentration <10% v/v O_2 fatal
- Alarm will activate at *19.5% v/v O_2

Enrichment:

Concentrations of O_2 above 20.9% v/v change properties of combustion

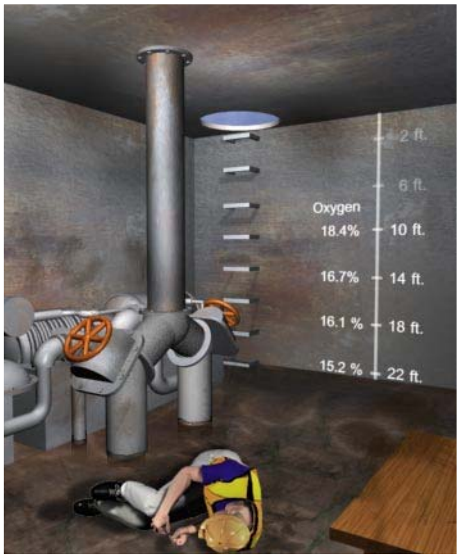
Combustible gases/vapours can ignite in concentrations lower than the LEL and explosions can be more violent

Alarm will activate at *23.5% v/v O_2

*** Factory default alarm value**

Causes of Oxygen Deficiency

- Displacement
- Microbial action
- Oxidation
- Combustion
- Absorption



IMPORTANT:

- the oxygen concentration may vary within a confined space
- monitoring the space at all levels prior to entry is essential
- ideally, for adequate warning of changes in atmospheric conditions each worker will be wearing a multi-gas monitor while working

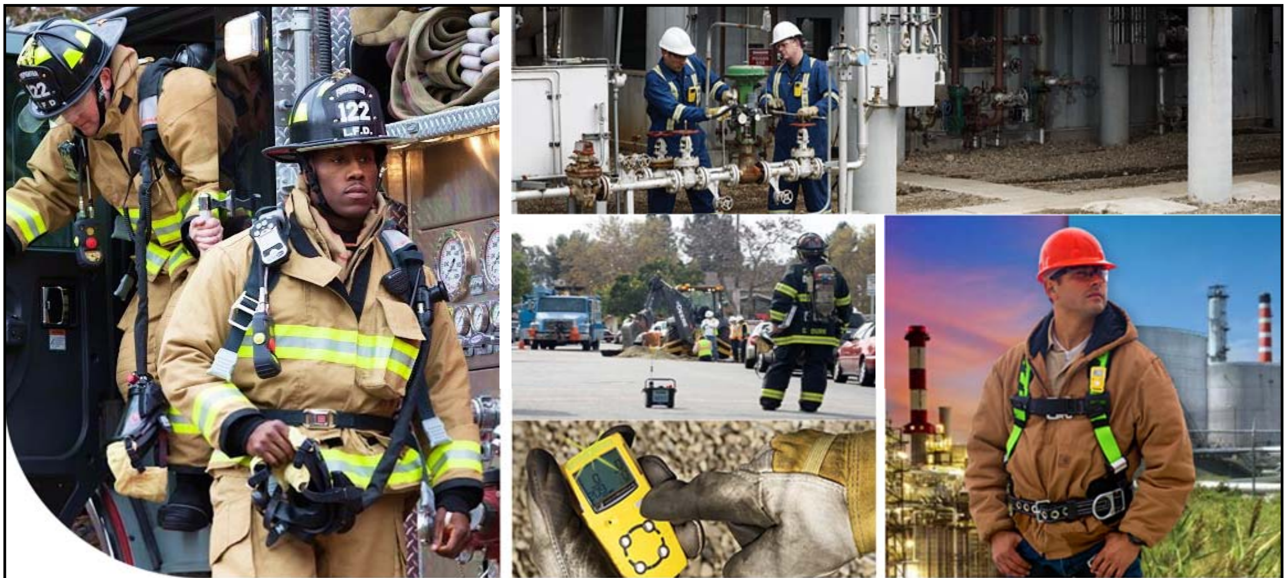
Oxygen Enrichment

- Proportionally increases the rate of many chemical reactions
- Hair and clothing can catch fire easily in oxygen enriched atmospheres
- Combustion is more violent; fires more fierce and harder to extinguish

Dartmouth General Hospital – 2014.01.14 – Fire Department feared explosion hazard – streets in vicinity closed as a precaution

Apollo 1 Oxygen Enrichment Tragedy

1967 January 27 - flash fire due to oxygen enriched atmosphere inside the Apollo 1 Command Module



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OXYGEN

Consumable anode oxygen sensor

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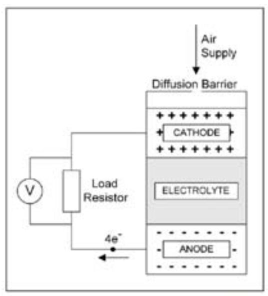
Consumable Anode Oxygen Sensor

Oxygen sensor performance

- Sensor generates electrical current proportional to the O_2 concentration
- Typical sensor life approximately 24 to 30 months



Oxygen Sensor Schematic

The rate at which O_2 enters the sensor is controlled by the size of the capillary pore – when O_2 reaches the working electrode (cathode) it is reduced to hydroxyl ions:

$$O_2 + 2H_20 + 4e^- \rightarrow 4OH^-$$

The hydroxyl ions migrate through the electrolyte to the lead anode where they are involved in oxidation of the lead forming lead oxide:

$$2Pb + 4OH^- \rightarrow 2PbO + 2H_2O + 4e^-$$

The overall sensor reaction can be represented as:

$$2Pb + O_2 \rightarrow 2PbO$$

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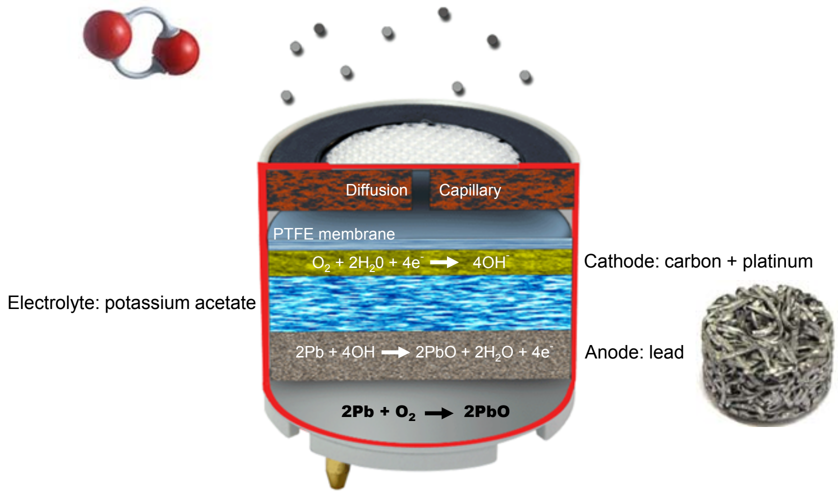
Consumable Anode Oxygen Sensor



Oxygen Sensor

- True percent by volume sensor
- Ability to adapt to changes in *pressure and *temperature
- Stable signal output up to end of operating life
- Sensor can be calibrated in ambient “fresh air”
- Can be stored for up to 6 months - store in sealed shipping container
- Oxygen specificity

* **May exhibit instability if changes are abrupt; sensor should stabilize**

O_2 Sensor Failure Mechanisms

Factors that lead to lower current output and sensor failure:

- All available surface area of Pb anode converted to PbO
- Electrolyte contaminated by exposure to:
  - High concentrations of acid gases - SO_2 and CO_2
  - Solvents
- Electrolyte leakage
- Desiccation
- Excessive heat
- Excessive humidity
- Blockage of capillary pore

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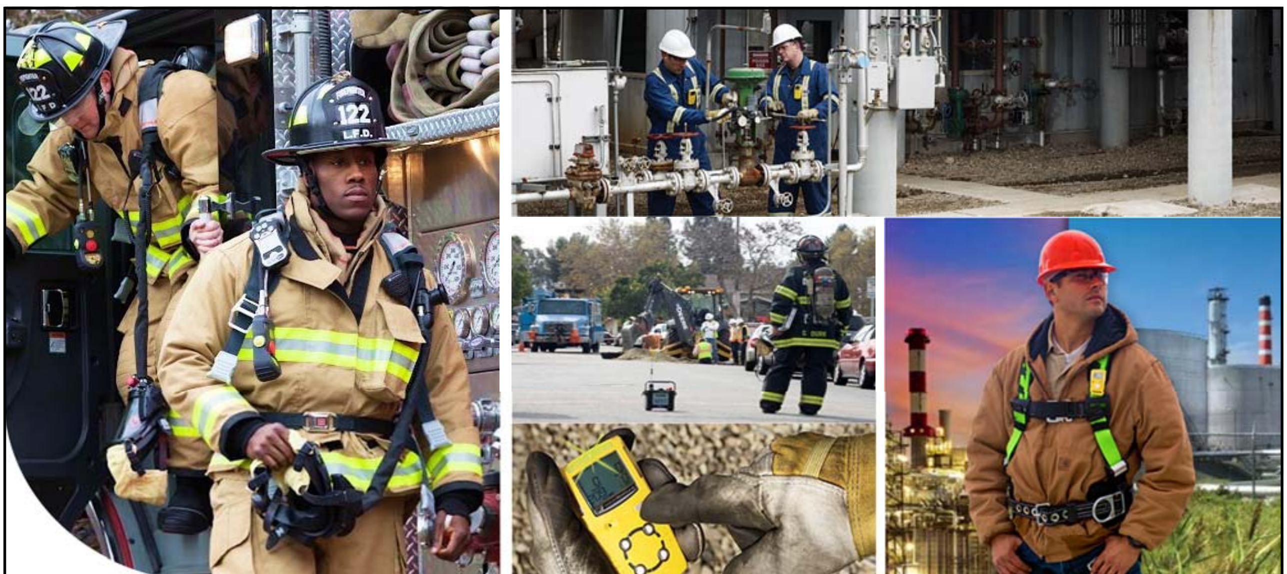

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OXYGEN
Long life, lead free oxygen sensor

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Oxygen Pump Technology

REACTION MECHANISM

Oxygen is reduced at the sensing electrode:

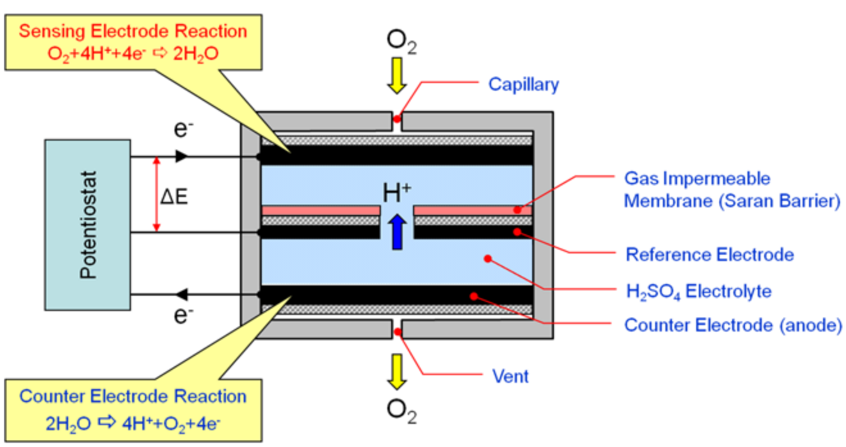
$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

Water is oxidised at the counter electrode:

$$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$$

As can be seen from the reaction mechanism, oxygen is generated at the counter electrode during operation of the sensor. These O_2 molecules must have an escape route to prevent migration to the sensing electrode which would result in a high false reading. The solution is a vent in the sensor directly beneath the counter electrode that facilitates an exhaust for the generated O_2 molecules.

Oxygen Pump Technology



Long Life Oxygen Sensor

Electrochemical Oxygen Sensor Performance Characteristics:

- Designed using field proven oxygen pump technology
- Extends sensor life by eliminating the consumable anode
- This is a lead free O_2 sensing technology
- Expected operating life of 5 years in air
- Exceptional performance in changing temperature and humidity
- Operating temperature range: -40ºC to 60ºC

Long Life Oxygen Sensor

Cautions:

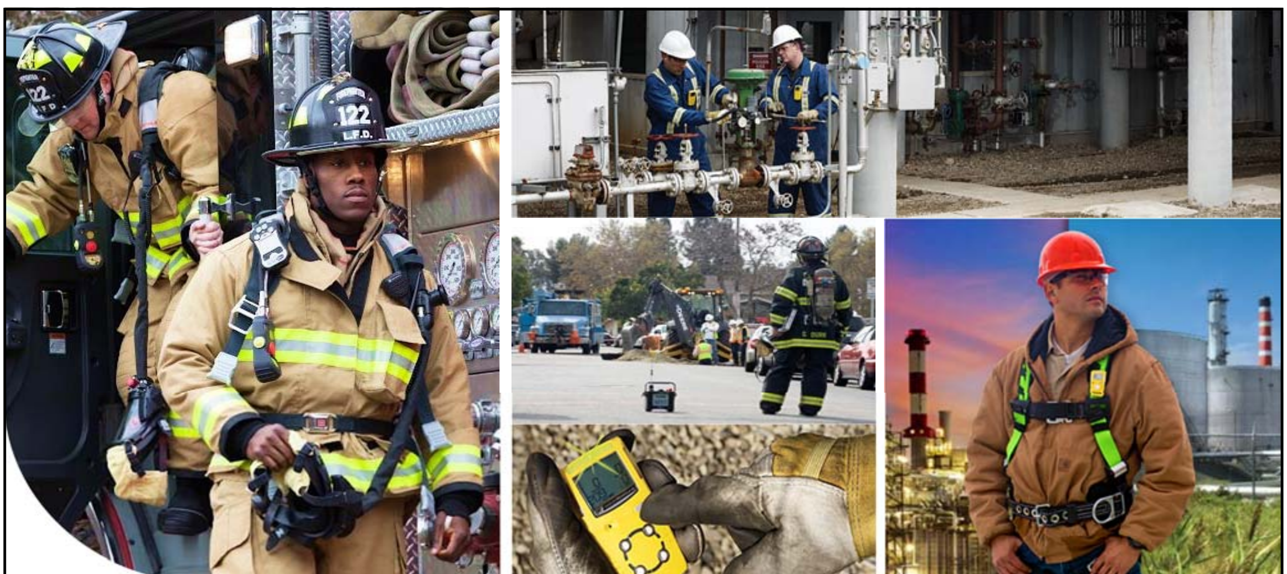
- Avoid exposure to high concentrations of solvent vapours during storage and use.
- Avoid close proximity exposure to alcohol containing antiseptic products such as wipes, sanitizing gels and liquids. Avoid handling after recent exposure to these products. Alcohols can generate an exaggerated sensor output and prolonged recovery times.
- High concentrations of CO_2 will affect accuracy and recovery time
- The lead free electrochemical oxygen sensor constantly requires a biased voltage to maintain stability. Allow new oxygen sensors approximately 30 minutes to stabilize before activating detector. The GasAlertMicroClip X3 circuitry maintains sensor stability; if batteries are allowed to completely deplete the sensor will require time to restabilize.

Long Life Oxygen Sensor

Cross Sensitivity Data

The 4OxLL CiTiceL has been tested with a number of gases which may be present in applications to establish their level of cross interference. Although this table does provide a guide, it does not dictate the behaviour of any particular sensor or batch of sensors. This behaviour may vary depending upon the application and ambient conditions.

Gas	Concentration	Balance	$\%O_2$ Equivalent
Ammonia, NH_3	37.5 ppm	21% O_2 / Balance N_2	$<-0.2\%O_2$
Carbon Dioxide, CO_2	5%	21% O_2 / Balance N_2	$0.015\%O_2$ / $\%CO_2$ (see note)
Carbon Dioxide, CO_2	10%	21% O_2 / Balance N_2	$0.015\%O_2$ / $\%CO_2$ (see note)
Carbon Monoxide, CO	1000 ppm	21% O_2 / Balance N_2	$<0.1\%O_2$
Chlorine, Cl_2	10 ppm	21% O_2 / Balance N_2	$<0.15\%O_2$
Ethanol, C_2H_5OH	150 ppm	21% O_2 / Balance N_2	$<0.1\%O_2$
Hydrogen, H_2	1000 ppm	21% O_2 / Balance N_2	$<-0.2\%O_2$
Hydrogen Sulfide, H_2S	50 ppm	21% O_2 / Balance N_2	$<0.1\%O_2$
Isobutylene, C_4H_8	75 ppm	21% O_2 / Balance N_2	$<0.1\%O_2$
Methane, CH_4	3.75%	21% O_2 / Balance N_2	$<-0.3\%O_2$
Nitrogen Dioxide, NO_2	10 ppm	21% O_2 / Balance N_2	$<0.1\%O_2$
Nitric Oxide, NO	25 ppm	21% O_2 / Balance N_2	$<0.1\%O_2$
Ozone, O_3	500 ppb	21% O_2 / Balance N_2	$<0.1\%O_2$
Sulfur Dioxide, SO_2	25 ppm	21% O_2 / Balance N_2	$<-0.1\%O_2$



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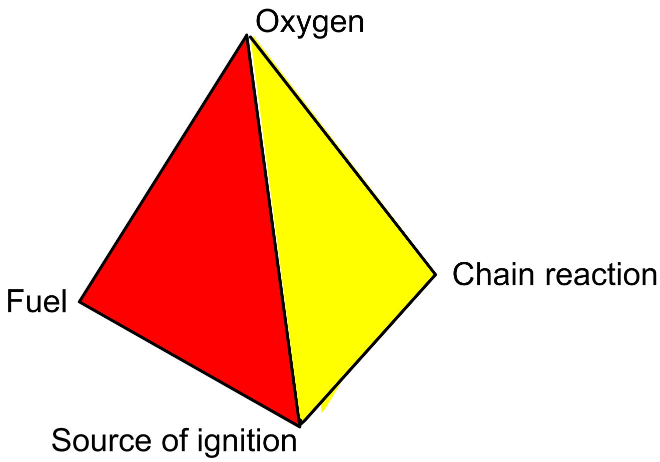
COMBUSTIBLE GASES

LEL…if you assume, things could go KABOOM!

Combustible gas hazards

West Texas fertilizer plant explosion 2013.04.18 – industrial fires and explosions are often catastrophic

Combustion Tetrahedron



Combustible Gases and Vapours

(L.E.L.) Lower Explosive Limit

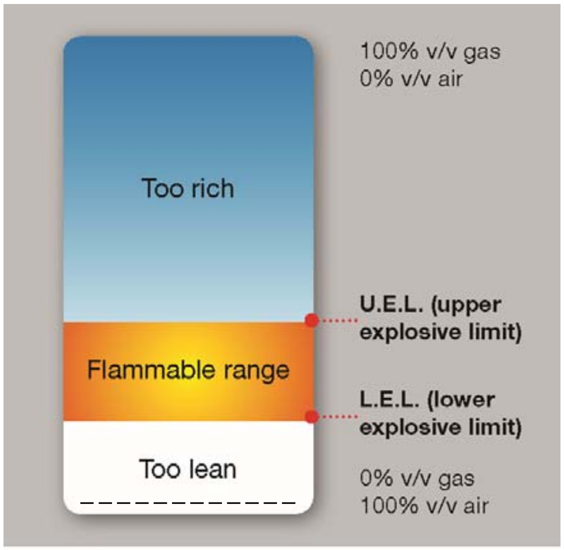
- Minimum concentration of a combustible gas or vapour in air which will ignite if a source of ignition is present

(U.E.L.) Upper Explosive Limit

- Maximum concentration in air that will support combustion

***most but not all combustible gases have an upper explosive limit, eg: acetylene; ethylene oxide**

Combustible Gas Measurement



Combustible gas detectors are intended to alarm conservatively at a low percentage of the Lower Explosive Limit, eg: 10% LEL

How Much is Too Much?

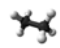
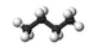
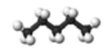
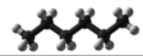
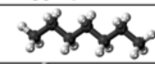
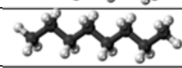
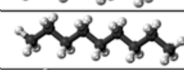
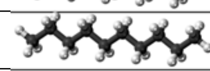
- Factory default alarm activation values set to: LOW 10% LEL; HIGH 20% LEL.
- This is the general hazardous condition threshold – be aware that the concentration of combustible gas can escalate rapidly
- Under Hot Work Permit conditions a 5% LEL alarm set point is often required
- It is important to understand that the combustible gas readings may underestimate the true concentration of combustible gas present; take appropriate action to a gas alarm!

Common Flammability Ranges

	LEL	UEL
Methane	5.0%	15.0%
Propane	2.2%	9.5%
Hydrogen	4.0%	75.0%
Butane	1.8%	8.4%
Pentane	1.4%	7.8%
Ethylene Oxide	3.0%	100.0%
Hydrogen Sulfide	4.3%	46.0%

Gases are not ideal

Unbranched Alkanes

Methane	CH_4	1 Carbon	
Ethane	C_2H_6	2 Carbon	
Propane	C_3H_8	3 Carbon	
Butane	C_4H_{10}	4 Carbon	
Pentane	C_5H_{12}	5 Carbon	
Hexane	C_6H_{14}	6 Carbon	
Heptane	C_7H_{16}	7 Carbon	
Octane	C_8H_{18}	8 Carbon	
Nonane	C_9H_{20}	9 Carbon	
Decane	$C_{10}H_{22}$	10 Carbon	

Properties of Different Combustible Gases

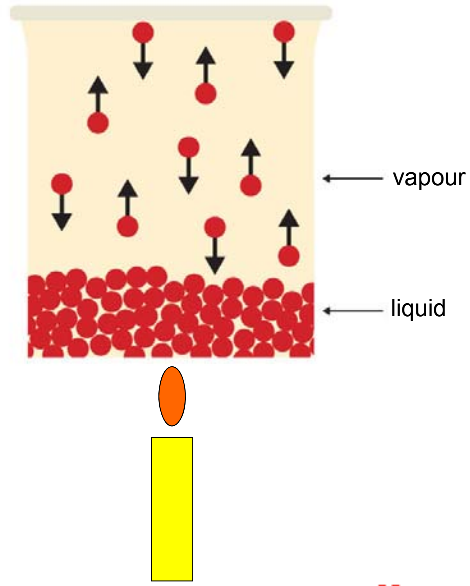
Hydrocarbon	Molecular Formula	State (25°C,101.3kPa)	Flash Point (°C)	% LEL v/v	Autoignition Temperature (°C)
Methane	CH_4	Gas	-188	5.0	537
Ethane	C_2H_6	Gas	-135	3.0	472
Propane	C_3H_8	Gas	-104	2.1	432
Butane	C_4H_{10}	Gas	-60	1.9	487
Pentane	C_5H_{12}	Liquid	-49	1.4	309
Heptane	C_6H_{14}	Liquid	-4	1.2	285
Hexane	C_7H_{16}	Liquid	-23	1.1	234
Octane	C_8H_{18}	Liquid	13	1.0	220

Note: figures subject to measurement methodologies

Vapours

Gaseous state of substances that are either liquids or solids at room temperatures
- Gasoline evaporates
- Dry ice (solid carbon dioxide) sublimates

Vapourization is a function of temperature
- Increasing the temperature of the combustible liquid increases the amount of vapour produced



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Flammable/Combustible Liquids:

	Flash Point Temp °C	Boiling Point °C	Examples
Class 1A Flammable Liquid	Below 22.8°C (73°F)	Below 37.8°C (100°F)	Ethylene Oxide Pentane Petroleum ether
Class 1B Flammable Liquid	Below 22.8°C (73°F)	Above 37.8°C (100°F)	MEK Toluene Gasoline Methanol
Class 1C Flammable Liquid	At or above 22.8°C (73°F)	Below 37.8°C (100°F)	Styrene Turpentine Xylene
Class II Combustible Liquid	At or above 37.8°C (100°F)	Below 60°C (140°F)	Diesel fuel Mineral spirits Kerosene
Class IIIA Combustible Liquid	At or above 60°C (140°F)	Below 93.3°C (200°F)	Home heating oil Naphthalenes Pine oil
Class IIIB Combustible Liquid	At or above 93.3°C (200°F)		Cooking oils lubricating oils Motor oil

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Flashpoint

Temperature at which a combustible liquid gives off enough vapour to form an ignitable mixture

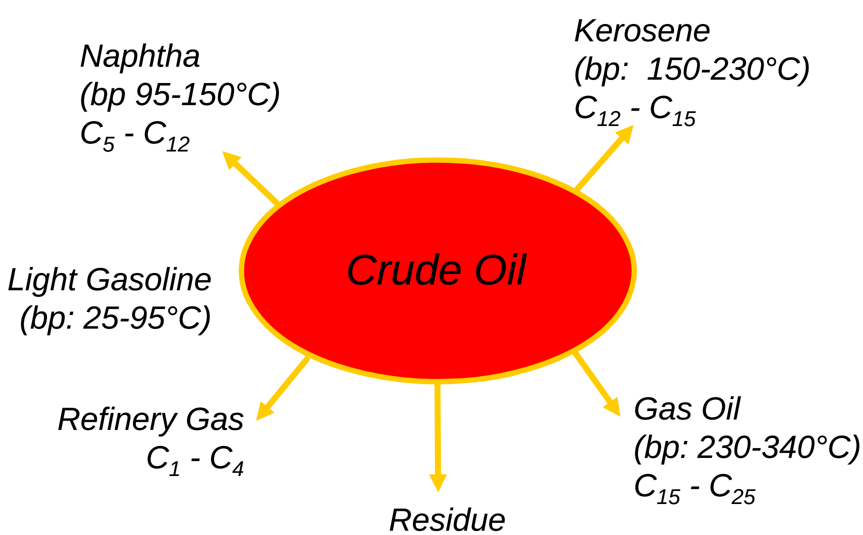
Common Flashpoints ºC / (º F)

- Kerosene/jet fuel	38 to 72 (100 to 162)
- Acetone	-18 (0)
- Methyl ethyl ketone	-4 (25)
- Ethanol (96 %)	17 (63)
- Diesel oil	38 to 88 (100 to 190)

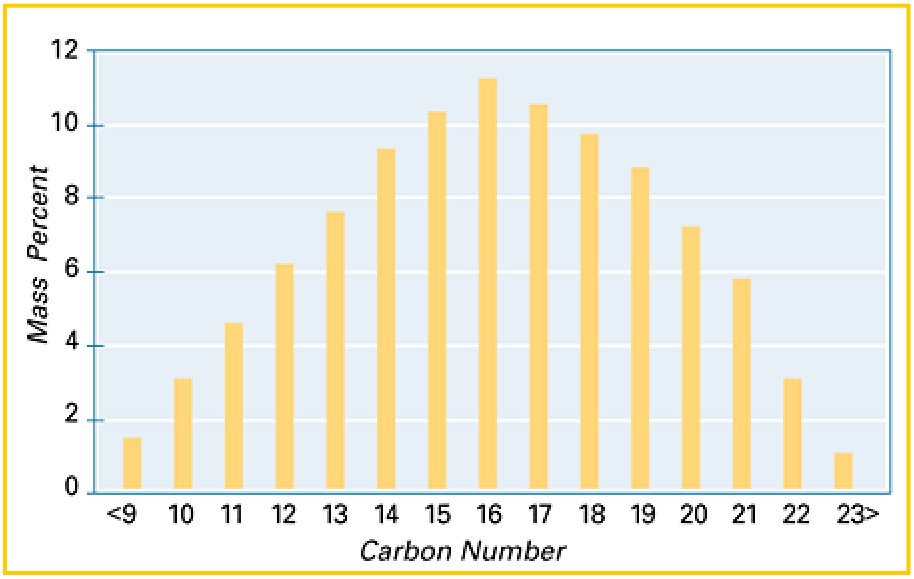
*General Guideline

Catalytic bead combustible gas sensors are not ideal for the detection of combustible liquids with flashpoints higher than 38°C (100°F); flashpoint should not be the only factor used to determine whether a gas is detectable in the % LEL range

Crude Oil Constituents



Typical Carbon Number Distribution in No. 2 Diesel Fuel



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Combustible Sensor Limitations

Contaminant	LEL (Vol %)	Flashpoint Temp (°F)	OSHA PEL	NIOSH REL	TLV	5% LEL in PPM
Acetone	2.50%	-4ºF (-20 ºC)	1,000 PPM TWA	250 PPM TWA	500 PPM TWA 750 PPM STEL	1250 PPM
Diesel (No.2) vapor	0.60%	125ºF (51.7ºC)	None Listed	None Listed	15 PPM	300 PPM
Ethanol	3.30%	55ºF (12.8 ºC)	1,000 PPM TWA	1000 PPM TWA	1000 PPM TWA	1,650 PPM
Gasoline	1.30%	-50ºF (-45.6ºC)	None Listed	None Listed	300 PPM TWA 500 PPM STEL	650 PPM
Hexane	1.10%	-7ºF (-21.7 ºC)	500 PPM TWA	50 PPM TWA	50 PPM TWA	550 PPM
Isopropyl alcohol	2.00%	53ºF (11.7ºC)	400 PPM TWA	400 PPM TWA 500 PPM STEL	200 PPM TWA 400 PPM STEL	1000 PPM
Kerosene/Jet Fuels	0.70%	100 – 162ºF (37.8 – 72.3ºC)	None Listed	100 mg/M3 TWA (approx 14.4 PPM)	200 mg/M3 TWA (approx 29 PPM)	350 PPM
MEK	1.40%	16ºF (-8.9ºC)	200 PPM TWA	200 PPM TWA 300 PPM STEL	200 PPM TWA 300 PPM STEL	700 PPM
Turpentine	0.8%	95ºF (35ºC)	100 PPM TWA	100 PPM TWA	20 PPM TWA	400 PPM
Xylenes (o, m & p isomers)	0.9 – 1.1%	81 – 90ºF (27.3 – 32.3 ºC)	100 PPM TWA	100 PPM TWA 50 PPM STEL	100 PPM TWA 150 PPM STEL	450 – 550 PPM

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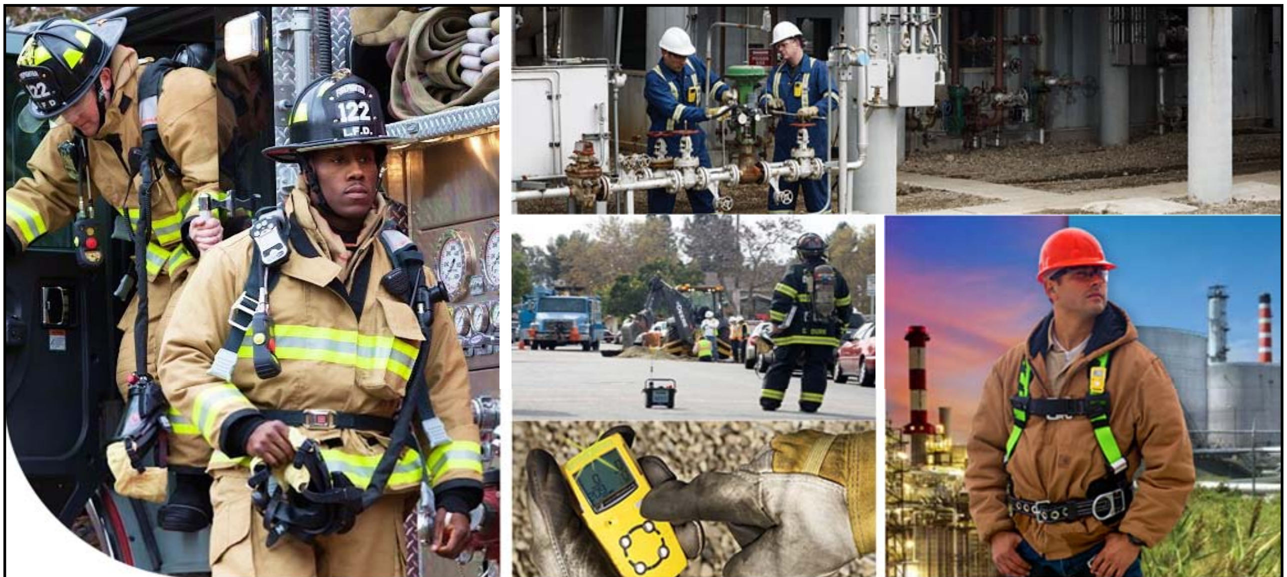

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2018 svcp

COMBUSTIBLE GASES

Catalytic bead combustible gas sensor

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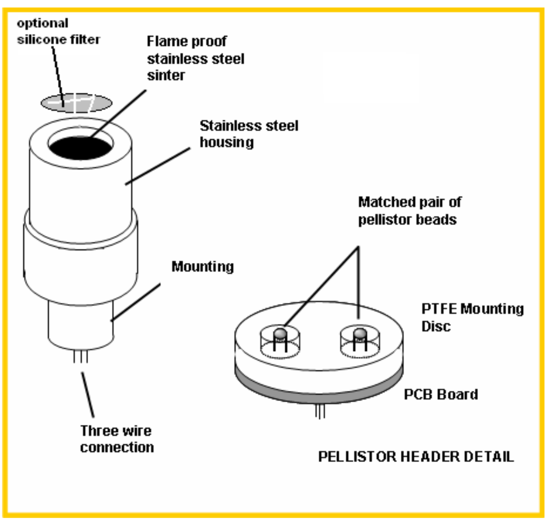
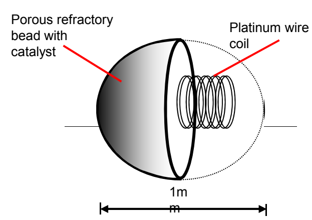
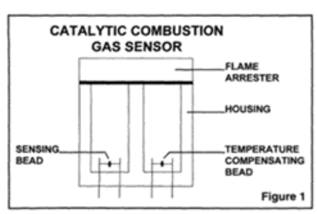
Catalytic Bead Combustible Sensor







Catalytic bead combustible sensors detect gas by a process called catalytic oxidation (combustion)

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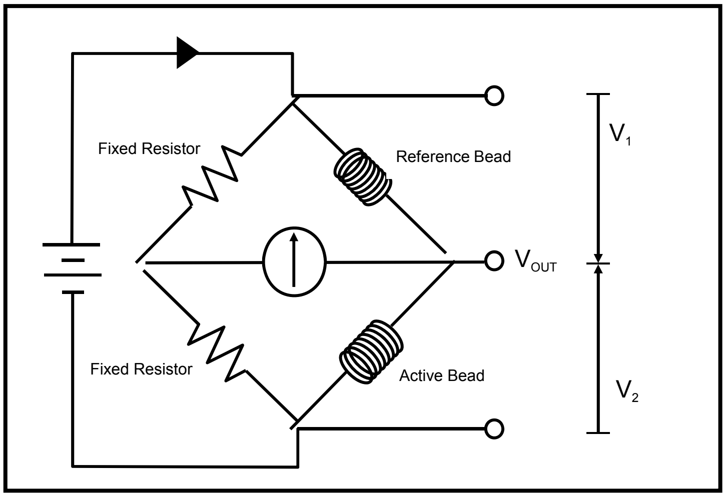
Catalytic Bead Combustible Sensor



Wheatstone Bridge Circuit

(In fresh air the Wheatstone Bridge Circuit is balanced [V_1 = V_2] = 0% LEL combustible gas)

Catalytic Bead Sensor Operation

Catalytic Bead Combustible Sensor

Principle of Operation:

- Detects combustible gas by catalytic oxidation (combustion), ie: the sensor burns combustible gas molecules
- The sensor housing contains two coils of very fine platinum wire that are encased in a porous alumina material to form two refractory beads – a voltage is applied to heat the wires - the beads are connected to opposing arms of a balanced Wheatstone bridge electrical circuit
- One bead (sensing) is coated with a catalyst material that enables catalytic oxidation of combustible gas molecules; the second bead (temperature compensating) is sealed and not capable of oxidation
- When exposed to combustible gas molecules an oxidation reaction causes the sensing bead wire to heat up, unbalancing the Wheatstone bridge circuit in relation to the concentration of combustible gas
- For catalytic oxidation to occur, oxygen must be present in sufficient concentration – **Do not rely on the combustible sensor readings if the oxygen concentration is less than 10% v/v.**

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Catalytic Bead Sensor

- LEL sensor only designed to detect 0-100% LEL concentration of combustible gas
- Sensor may be damaged by exposure to higher than 100% LEL concentrations
- To prevent damage sensor is switched OFF when the concentration exceeds 100% LEL and OL (Over Limit) is displayed
- Do not rely on catalytic bead combustible gas sensor readings if the O_2 concentration is ≤10% v/v
- Sensor can be permanently damaged by exposure to substances commonly referred to as “poisons”
- The catalytic bead sensor technology is non-specific

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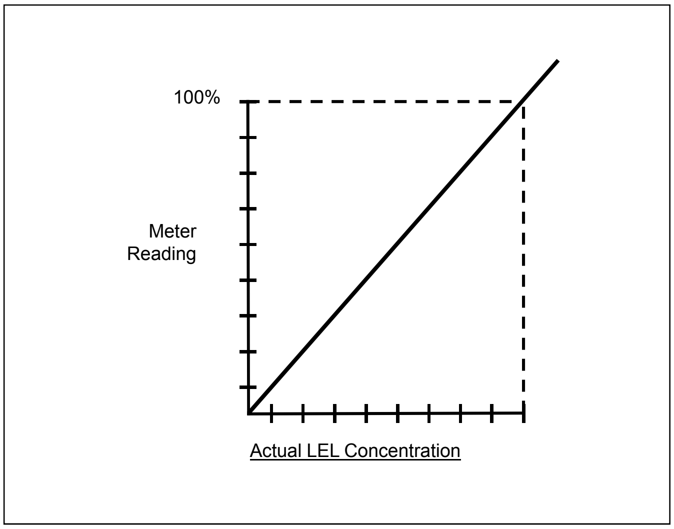
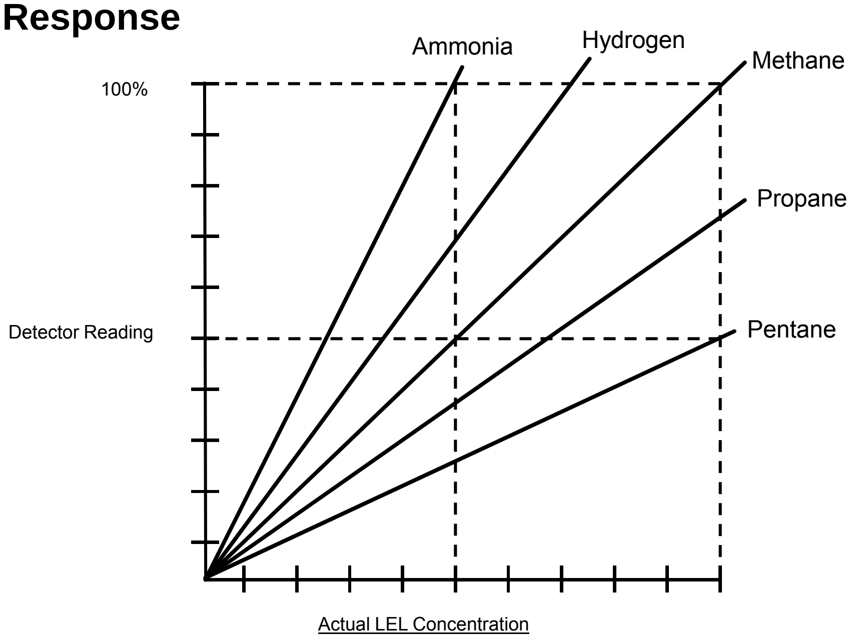
Linear Response



Calibration Standard

Relative Response



LEL Sensor Relative Response

Relative Response of a Combustible Sensor

Combustible gas / vapor	Relative response when calibrated on pentane	Relative response when calibrated on propane	Relative response when calibrated on methane
Hydrogen	2.2	1.7	1.1
Methane	2.0	1.5	1.0
Propane	1.3	1.0	0.65
n-Butane	1.2	0.9	0.6
n-Pentane	1.0	0.75	0.5
n-Hexane	0.9	0.7	0.45
n-Octane	0.8	0.6	0.4
Methanol	2.3	1.75	1.15
Ethanol	1.6	1.2	0.8
Isopropyl Alcohol	1.4	1.05	0.7
Acetone	1.4	1.05	0.7
Ammonia	2.6	2.0	1.3
Toluene	0.7	0.5	0.35
Gasoline (Unleaded)	1.2	0.9	0.6

* As example only. Data based on sensors without enhanced poison resistant filter. Actual relative response data may vary.

Correction Factors

Correction factor is the reciprocal of relative response

- Consider detector calibrated on methane, then used to monitor pentane

When calibrated on methane, sensor shows a relative response to pentane of *0.5

- In other words, readings will be 50% lower than actual

Correction factor calculated as: 1 / 0.5 = 2.0

- detector calibrated to methane – reading is 10% LEL – gas being detected is pentane actual concentration of pentane is 20% LEL (10 x 2 = 20)

NOTE:

- Even if a correction factor is used the catalytic bead combustible gas sensor is still a non-specific gas sensing technology.
- It is important to fully understand the use of corrections factors if implementing in your gas detection safety program.

*** Actual relative response may vary**

Poisons and Inhibitors

Poisoning:

- Some compounds will decompose on the catalyst and form a solid barrier over the catalyst surface. This action is cumulative and prolonged exposure results in an irreversible decrease in the sensors detection capabilities. The most common poisoning substances are: silicones, phosphates and lead or sulphur containing compounds.

Inhibition:

- Certain other compounds, especially H_2S and halogenated hydrocarbons (Freons®, trichloroethylene, methylene chloride, etc.), are absorbed, or form compounds that are absorbed, by the catalyst. This absorbtion can block catalytic sites and inhibit the normal response of the sensor. The resultant loss of sensitivity can be temporary and in most cases the sensor will recover following a period of operation in "fresh air".

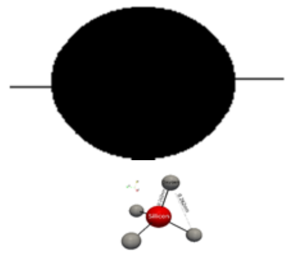
*** Some compounds may exhibit inhibition characteristics and then become a sensor poison if exposure time and concentration exceed sensor resistance capabilities.**

Inadvertent sensor poisoning?

- **Volatile silicones:**
  - Lubricants such as WD-40
  - Rust inhibitors
  - Plastic and rubber revival products such as ARMOR ALL
  - Waxes and polishes
  - Hand lotions, personal care products and makeup with ingredients such as cyclomethicone, & polydimethylsiloxanes
  - Heat transfer fluids
  - Silicone greases and oils
  - Caulking materials…
- **Hydrogen Sulphide and other Sulphur containing compounds**
- **Phosphates and phosphorus containing substances**
- **Lead containing compounds (especially tetraethyl lead)**
- **Over Exposure to combustible gases**

Catalytic bead technology

POISONING



Volatile silicone molecules can cause permanent damage to catalytic bead sensors

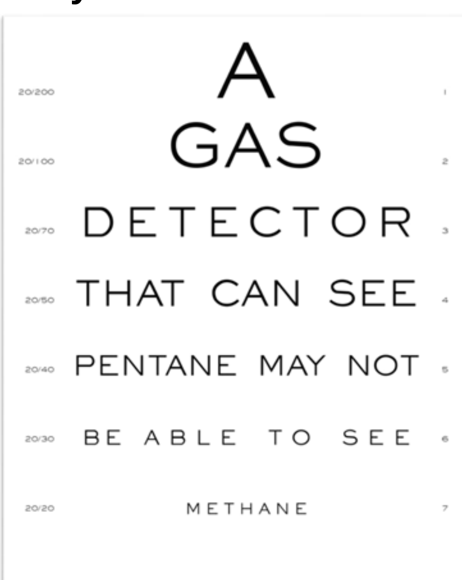
Monitor Cleaning

- In addition to the use of a soft damp cloth as recommended in the BW User Manual the only endorsed cleaner is ACL Staticide
- Avoid exposing the sensor screens to moisture – do not use computer keyboard air dusters to clean debris from sensor filters
- BW do not recommend the use of products such as EconoClean, alcohol based cleaners, citrus based cleaners or products such as Armor All to clean dirty gas detector housings

Why Methane is our Factory Default Gas

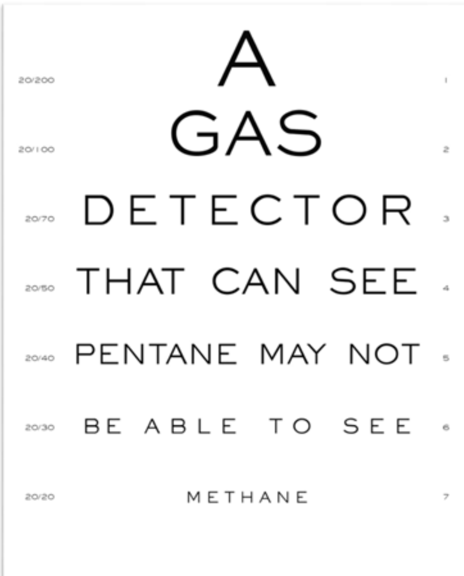
- Is methane the right gas for calibration and bump testing as BW recommend?
- Is pentane the right gas for calibration and bump testing as some other manufacturers' recommend?
- What if I work at a propane plant; should I still calibrate to methane or pentane?
- I'm so confused?

Why Methane?



- If methane is a potential combustible gas hazard, calibration and BUMP testing with methane provides the ***safest*** approach
- Methane is the most commonly encountered combustible gas hazard
- Methane is the most difficult of the standard alkanes for the catalytic bead sensor technology to detect

Why Methane?



- Pentane calibration and BUMP testing does not guarantee methane is detectable
- If the detector can detect methane, it can detect pentane
- If the combustible gas hazard is known, calibrate and BUMP test using the appropriate target gas

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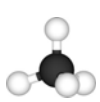
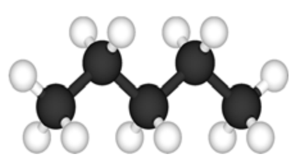
Heat of Combustion

Name	Formula	Heat – kJ/mol	Auto-ignition Temperature (ºC)
Methane	CH_4	881.6	537
Propane	C_3H_8	2201.0	432
Pentane	C_5H_{12}	3491.1	309
Octane	C_8H_{18}	5458.9	220

Source for heats of combustion: Heats of Combustion of Organic Compounds by M. S. Kharasch, pg. 373


CH_4


$C_5 H_{12}$

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Pentane Equivalent Response Strategies

- To provide pentane sensitivity and ensure that the catalytic bead sensor is capable of detecting methane BW provide a "pentane equivalent" quad gas mixture - the pentane equivalent mixture contains 1.25% v/v methane gas – the **"best of both worlds"**
- The sensor is calibrated to 25% LEL gas but the span value is left at 50% giving the same alarm on the side of safety response you would have with a pentane calibrated sensor in a methane atmosphere
- Lower factory default alarm set points from 10 and 20% LEL to 5 and 10% LEL.
- Calibration to a combustible gas other than methane may be right for some applications. If you work at a propane plant and propane is the primary combustible gas hazard calibrate to propane; if you work at a plant that manufactures butane lighters, calibrate to butane.

Methane Based Equivalent Calibration Gas Mixtures

Combustible Gas / Vapor	Relative response when sensor is calibrated to 2.5% (50% LEL) methane	Concentration of methane used for equivalent 50% LEL response
Hydrogen	1.1	2.75% CH4
Methane	1	2.5% Vol CH4
Ethanol	0.8	2.0% Vol CH4
Acetone	0.7	1.75% Vol CH4
Propane	0.65	1.62% Vol CH4
n-Pentane	0.5	1.25% Vol CH4
n-Hexane	0.45	1.12% Vol CH4
n-Octane	0.4	1.0% Vol CH4
Toluene	0.35	0.88% Vol CH4

Silicone Filtered vs Unfiltered Response

- All BW products factory default combustible gas sensor is filtered to help protect against airborne poisons such as volatile silicone vapours.

Silicone Filtered vs Unfiltered Response

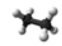
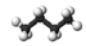
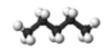
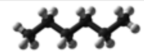
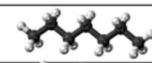
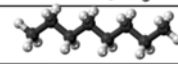
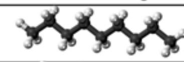
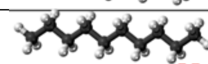
- There is a trade off portable safety gas detector users need to be aware of – the filter helps prevent catalytic bead sensor poisoning and therefore last longer, but it restricts some hydrocarbons that are detectable by an unfiltered sensor!

- A combustible sensor with the poison resistant filter is typically not recommended for the detection of:
  - higher hydrocarbons – C_7 and above; benzene ring molecules; gasoline, diesel…
  - Alcohols – methanol, ethanol, isopropanol,…
  - Ketones – acetone, methyl ethyl ketone (MEK),…
  - Esters – acetate, butyl acetate, ethyl acetate,…
  - etc…

* Each value has been rounded off to the nearest 5%. ** Ammonia response based on extended exposure.

Unbranched Alkanes

Relative Sensitivity is related to the rate of diffusion – the larger the molecule, the slower the rate of diffusion, the lower the Relative Sensitivity

Methane	CH_4	1 Carbon	
Ethane	C_2H_6	2 Carbon	
Propane	C_3H_8	3 Carbon	
Butane	C_4H_{10}	4 Carbon	
Pentane	C_5H_{12}	5 Carbon	
Hexane	C_6H_{14}	6 Carbon	
Heptane	C_7H_{16}	7 Carbon	
Octane	C_8H_{18}	8 Carbon	
Nonane	C_9H_{20}	9 Carbon	
Decane	$C_{10}H_{22}$	10 Carbon	

Catalytic Bead Sensor Operation

GasAlertQuattro Combustible Sensor Response

Relative Sensitivity

The table below illustrates the relative sensitivity of the CiTipeL 4P75C catalytic bead combustible gas sensor to a range of gases and vapours at the same %LEL concentration. The values are experimentally derived and expressed relative to methane calibration at 2.5% v/v (50%LEL) concentration. CH_4 signal = 100.

NOTE: The results are intended for guidance only; actual response may vary. For the most accurate results, calibrate a sensor using the target gas when possible.

Gas / Vapour	Relative Sensitivity*	Gas / Vapour	Relative Sensitivity*
Methane	100	Carbon monoxide	120
Propane	65	Hydrogen	110
N-Butane	65	Ammonia**	140
N-Pentane	55	Cyclohexane	80
N-Hexane	60	Ethylene	95
Acetylene	90	1,2 Butadiene	60

* Each value has been rounded off to the nearest 5%. ** Ammonia response based on extended exposure.

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GasAlertQuattro Combustible Sensor Response

Relative Sensitivity

The table below illustrates the relative sensitivity of the CiTipeL 4P75 catalytic bead combustible gas sensor to a range of gases and vapours at the same %LEL concentration. The values are experimentally derived and expressed relative to methane calibration at 2.5% v/v (50%LEL) concentration. CH_4 signal = 100.

NOTE: The results are intended for guidance only; actual response may vary. For the most accurate results, calibrate a sensor using the target gas when possible.

Gas / Vapour	Relative Sensitivity*	Gas / Vapour	Relative Sensitivity*
Methane	100	Carbon monoxide	120
Propane	65	Acetone	70
n-Butane	65	Methyl ethyl ketone	55
n-Pentane	55	Toluene	40
n-Hexane	55	Ethyl acetate	55
n-Heptane	45	Hydrogen	110
n-Octane	35	Ammonia**	140
Methanol	85	Cyclohexane	50
Ethanol	85	Leaded Petrol	60
isopropyl alcohol	65	Unleaded Petrol	60
Acetylene	90	Ethylene	90
1, 3 Butadiene	60		

* Each value has been rounded off to the nearest 5%. ** Ammonia response based on extended exposure.

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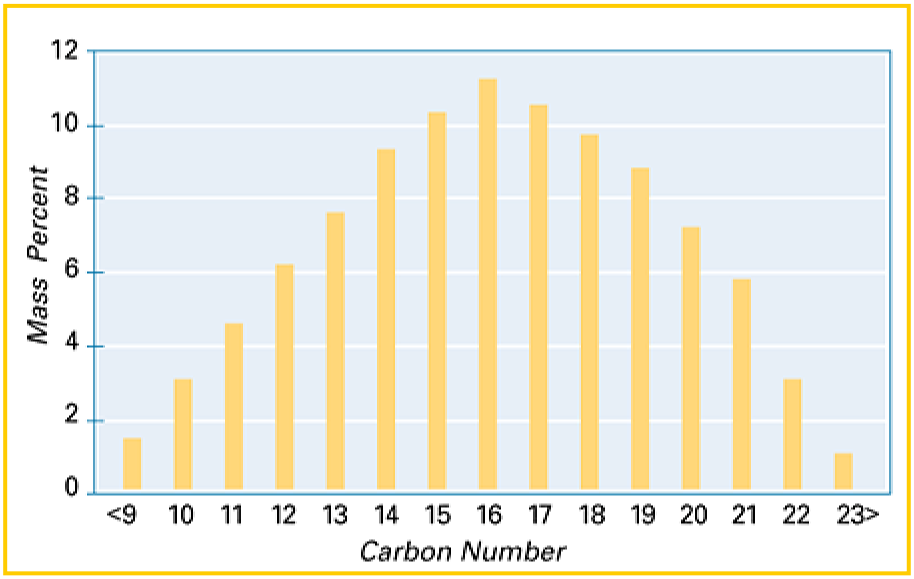
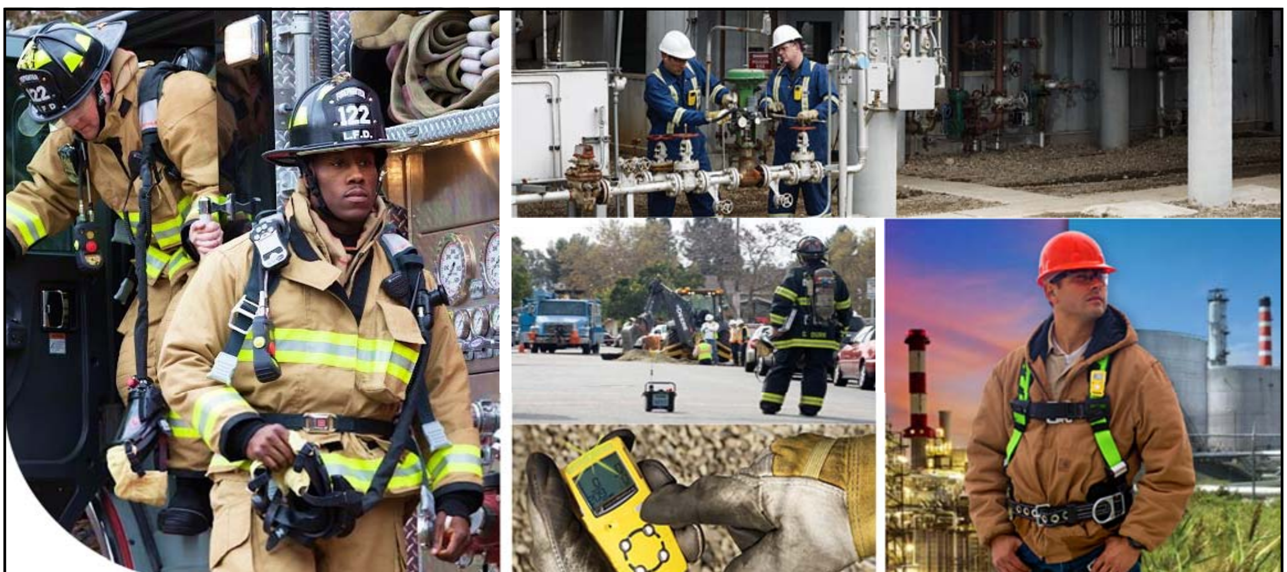
Typical Carbon Number distribution in No. 2 Diesel Fuel





TOXIC GASES

I can smell H_2S. What do I need a detector for? CO, the silent killer!

Its Rotten Egg Smell is Easily Detected…

Excerpt from a Toronto Star article 2011 May 01

RCMP say three workers were doing maintenance on a gas line off Highway 47 near Fox Creek on Saturday evening when hydrogen sulphide began to leak. Firefighters from Fox Creek donned breathing packs and were able to get two workers out, but one of the workers died at the scene.

Hydrogen Sulphide is extremely toxic and occurs in natural gas as a result of decaying organic matter that contains Sulphur. **Its rotten-egg smell is easily detected at low concentrations, but at higher levels can paralyze the olfactory nerves, meaning a person may be in the most danger when they can no longer smell it.**

The Source of the Deadly Gas was a Car…

Excerpt from the Calgary Herald 2014 July 01

A fatality inquiry report into a senior's death from carbon monoxide poisoning calls for better public education of Albertans about the dangers of the toxic gas.

Susannah Klassen died and seven occupants of Sunshine Villas were hospitalized in 2008 after the **odorless** fumes entered their condominium complex. The source of the deadly gas was a car that had been left running in a parking garage, producing levels that were more than 10 times above those needed to trigger a detector and high enough to cause convulsions and coma.

Chlorine Gas is Particularly Insidious…

Excerpt from Environmental Health News 2011 October 20

The worst chlorine gas accident in the USA occurred in 2005, when 18 freight cars derailed and released 120,000 pounds of chlorine gas in the mill town of Graniteville, S.C. Nine people were killed and at least 1,400 were exposed, resulting in more than 550 people treated at hospitals, including some with serious lung injuries.

Chlorine gas is particularly insidious. Even small exposures can trigger coughing, choking, wheezing, and burning of the eyes, skin and throat. Inhaling large amounts constrict the airways by inflaming the lining in the throat and lungs. At the same time, fluid accumulates in the lungs, making it doubly hard to breath. People can literally drown in their own body fluids. **At high exposures, a few deep breaths are lethal.**

Toxic Atmospheres Come From

- Microbial action on material in CS
- Products or chemicals stored in CS
- Work being performed in CS
- Areas adjacent to Confined Space

Gas Exposure Alarms

Oxygen:
- LOW oxygen concentration
- HIGH oxygen concentration

Combustible:
- Instantaneous LOW and HIGH

Toxic Gases:
- Instantaneous LOW and HIGH
- TWA
- STEL

*** Remember: gas alarm set points are set very conservative to provide early warning so workers can evacuate an area safely.**

Time Weighted Average - TWA

Definition:

TWA – Time-weighted average exposure concentration for a conventional 8-hour (TLV, PEL) or up to a 10-hour (REL) workday and a 40 hour workweek.

TWA exposure is determined by averaging readings while the detector is running

When monitoring session less than eight hours, TWA projected for the full eight hour shift.

When monitoring session more than 8 hours, TWA calculated on an "equivalent" 8 hour shift basis

According to OSHA cumulative TWA exposures for an eight hour work shift are calculated as follows:

$$E = (C_a * T_a + C_b * T_b + \ldots C_n * T_n) / 8$$

- E is the equivalent exposure for the eight hour working shift
- C is the concentration during any period of time T where the concentration remains constant
- T is the duration in hours of the exposure at concentration C

Example:

$$TWA = \frac{11\ ppm * 4\ hr + 14\ ppm * 2\ hr + 20\ ppm * 2hr}{4\ hr + 2\ hr + 2hr}$$

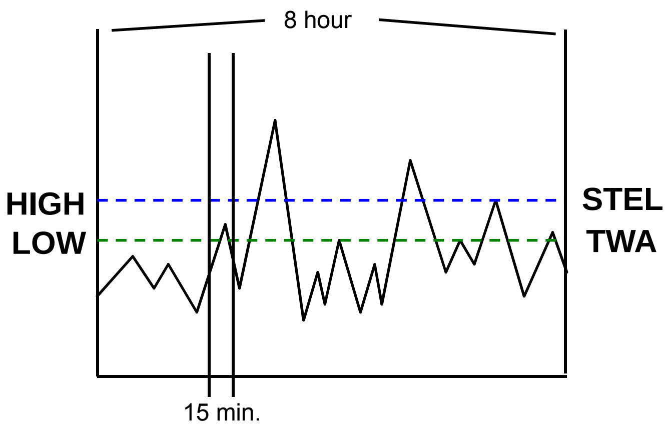
$$TWA = \frac{44\ ppmhr + 28\ ppmhr + 40\ ppmhr}{8\ hr}$$

$$TWA = \frac{112\ ppmhr}{8\ hr} = 14\ ppm$$

Short Term Exposure Limit – STEL

- Short Term Exposure Limit (STEL) is the maximum permissible gas concentration a worker can safely be exposed to for short periods of time (5 – 15 minutes maximum) Some gases and vapors have an allowable maximum Short Term Exposure Limit which is higher than the 8 hour TWA
- Many gas hazards may not have a STEL value recommendation – typically can be calculated as a multiple of the TWA value – consult local regulations for advice
- STEL values usually calculated as 15 minute, or in some cases, as 5 minute or 10 minute time weighted averages

Toxic Gas Exposure Measurement



Typically, direct reading portable safety gas detectors provide 4 separate alarm settings for toxic gases: Instantaneous LOW / Instantaneous HIGH / TWA / STEL – for most toxic gases the LOW and HIGH alarm set points are based on the TWA and STEL values

Permissible Exposure Limit (PEL)

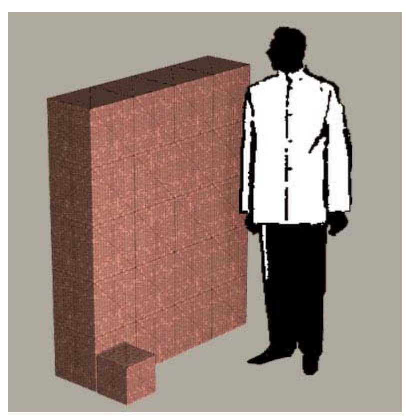
- Determined by **OSHA**
- Sets limits for legal unprotected worker exposure to a listed toxic substance
- Force of law in USA!
- Individual states free to enact stricter, but never less conservative limits
- Given in “Parts-per-Million” (ppm) concentrations
  - 1 % v/v = 10,000 ppm

OSHA®
Occupational Safety
and Health Administration

Permissible Exposure Limits

“Parts-per-Million” (ppm) concentrations

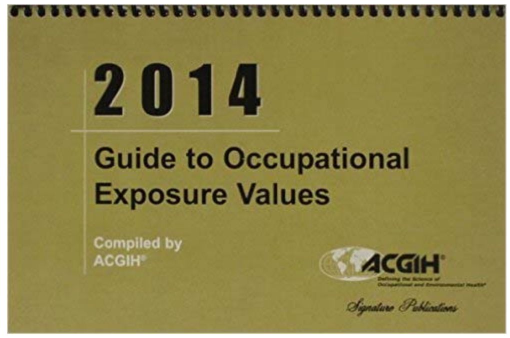
- 1.0 ppm the same as:
  - One automobile in bumper-to-bumper traffic from Cleveland to San Francisco
  - One inch in 16 miles
  - One minute in two years
  - One ounce in 32 tons
  - One cent in $10,000



1 million pennies

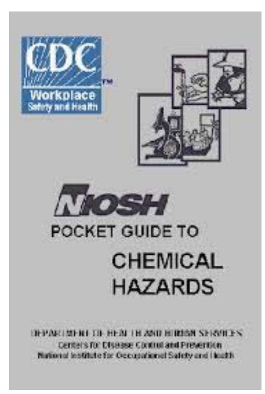
Threshold Limit Value

- Determined by American Conference of Governmental Industrial Hygienists (ACGIH)
- Guidelines for control of potential health hazards
- Intended as recommendation – only becomes law when adopted by governmental entities



NIOSH Recommended Exposure Limit

- Determined by National Institute of Occupational Safety and Health (NIOSH)
- NIOSH is part of the US Center for Disease Control (CDC)
- Guidelines for control of potential health hazards
- Intended as recommendation but incorporated by adoption in many states with OSHA approved safety and health plans



Factory Default Alarm Setpoints

	TWA	STEL	Low	High
Hydrogen Sulfide	10 ppm	15 pm	10 ppm	15 ppm
Sulfur Dioxide	2 ppm	5 ppm	2 ppm	5 ppm
Hydrogen Cyanide	4.7 ppm	10 ppm	4.7 ppm	10 ppm
Carbon Monoxide	35 ppm	200 ppm	35 ppm	200 ppm
Chlorine	0.5 ppm	1.0 ppm	0.5 ppm	1.0 ppm
Nitric Oxide	2 ppm	2 ppm	2 ppm	2 ppm
Nitrogen Dioxide	2 ppm	5 ppm	2 ppm	5 ppm
Ammonia	25 ppm	35 ppm	25 ppm	50 ppm
Phosphine	0.3 ppm	1.0 ppm	0.3 ppm	1.0 ppm
Ethylene Oxide	1 ppm	5 ppm	1 ppm	5 ppm
Chlorine Dioxide	0.1 ppm	0.3 ppm	0.1 ppm	0.3 ppm
Ozone	0.1 ppm	0.1 ppm	0.1 ppm	0.2 ppm
Oxygen	N/A	N/A	19.5% v/v	23.5% v/v
Combustible	N/A	N/A	10% LEL	20% LEL
Carbon Dioxide	5,000 ppm	30,000 ppm	5,000 ppm	30,000 ppm

Applications by Gas Hazard

	Comb	O_2	CO	H_2S	SO_2	NH_3	Cl_2	ClO_2	CO_2	H_2	HCN	NO	NO_2	O_3	PH_3	VOCs
Agriculture	•	•	•	•		•			•			•	•		•	
Aircraft Maintenance	•	•	•						•							•
Chemical Manufacturing	•	•	•	•	•	•				•		•	•			
Clandestine Drug Labs	•	•				•									•	•
Construction	•	•	•	•								•	•			•
Electrical Utilities	•	•	•	•	•									•		
Fire Departments	•	•	•	•							•					•
Food/Beverage Manufacturing	•	•	•	•		•			•		•				•	•
Gas Utilities	•	•		•												
HazMat Response	•	•	•	•	•	•	•			•	•				•	•
Manufacturing	•	•	•	•					•							•
Mining	•	•	•	•							•	•	•			
Oil/Gas Production	•	•	•	•		•										•
Petrochemical and Refining	•	•	•	•		•				•						•
Pulp and Paper	•	•	•	•	•	•	•	•								•
Pharmaceutical	•	•		•	•	•										•
Power Plants	•	•	•	•						•						
Public Works	•	•	•	•								•	•	•		
Shipyards	•	•	•	•					•			•				•
Steel Mills/Foundries	•	•	•	•							•		•			•
Water/Wastewater Treatment	•	•	•	•	•	•								•		•
Welding	•	•	•									•	•	•		

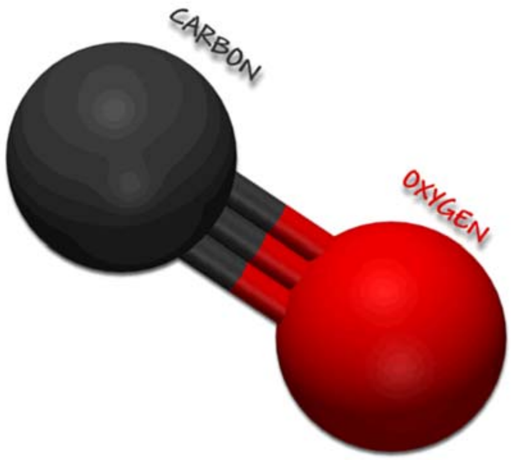
Carbon Monoxide

Molecular formula: CO
Molecular weight: 28.01 g/mol
LEL: 12.5% v/v
UEL: 74.2% v/v
Characteristics: colourless, odourless

Sources of CO:

- Automobile exhaust
- Generators and other gasoline powered equipment
- Worn, or poorly adjusted and maintained combustion devices such as furnaces, heaters, boilers
- Welding equipment
- Wood stoves, fireplaces
- Tobacco smoke
- Fires – house, building, wild fires

Carbon monoxide is the most commonly encountered toxic gas hazard!



Carbon Monoxide

Symptoms of exposure:

- Headaches
- Fatigue
- Nausea and other "Flu-like" symptoms
- Loss of consciousness
- Brain damage
- Coma
- Death

Physiological effects:

- Carbon monoxide enters the body through inhalation. Once in the lungs the gas molecules pass through capillaries to the blood stream. In the blood stream the carbon monoxide molecules are easily absorbed by red blood cells blocking oxygen molecules from these cells which denies the body of oxygen.

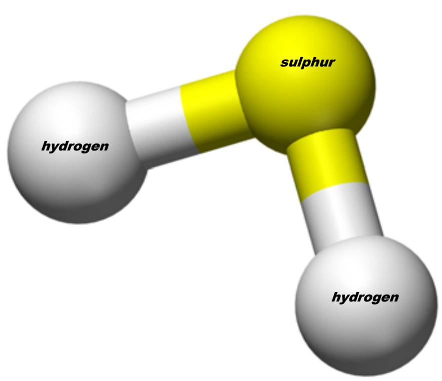
Toxic Effects CO

Concentration (ppm)	Symptoms
35	Headache and dizziness within 6 to 8 hours of constant exposure
100	Headache within 2 to 3 hours of constant exposure
200	Headache and impaired judgement within 2 to 3 hours
400	Headache within 1 to 2 hours
800	Immediate headache, dizziness, nausea – convulsions within 45 minutes – incapacitation within 2 hours
1,200	IDLH concentration – CDC NIOSH Pocket Guide to Chemical Hazards
1,600	Immediate headache, dizziness, nausea – death in <2 hours
12,800	Unconciousness in 2 to 3 breaths – death in <3 minutes

Effects may vary by individual

Hydrogen Sulphide

Molecular formula: H_2S
Molecular weight: 34.08 g/mol
LEL: 4.3% v/v
UEL: 46.0% v/v
Characteristics: colourless, rotten egg odour in low concentrations; odour threshold varies, but is well below 1 ppm concentrations of 150 to 200 ppm will paralyze the olfactory nerve.



Sources of H_2S:
- Hydrocarbon deposits
- Natural gas
- Petroleum crude
- Volcanic gases
- Sulphur springs
- Sewer gases
- Landfills
- Pulp and Paper (anaerobic fermentation of pulp)

Hydrogen Sulphide

Symptoms of exposure:

- Offensive odour
- Tearing of the eyes
- Nausea, headache, loss of appetite
- Bronchial constriction, difficulty breathing
- Olfactory fatigue
- Respiratory tract irritation, inflammation of the eyes, pulmonary edema
- Breathing cessation
- Death

Physiological effects:

- Hydrogen sulphide enters the body through inhalation. In the blood stream the hydrogen sulphide molecules are easily absorbed by red blood cells blocking oxygen molecules from these cells which denies the body of oxygen. Hydrogen sulphide effectively kills cells by neurtalizing the mitochondria and damaging cell structure. Hydrogen sulphide neutralizes the phrenic nerve which controls the diaphragm and breathing will cease. .

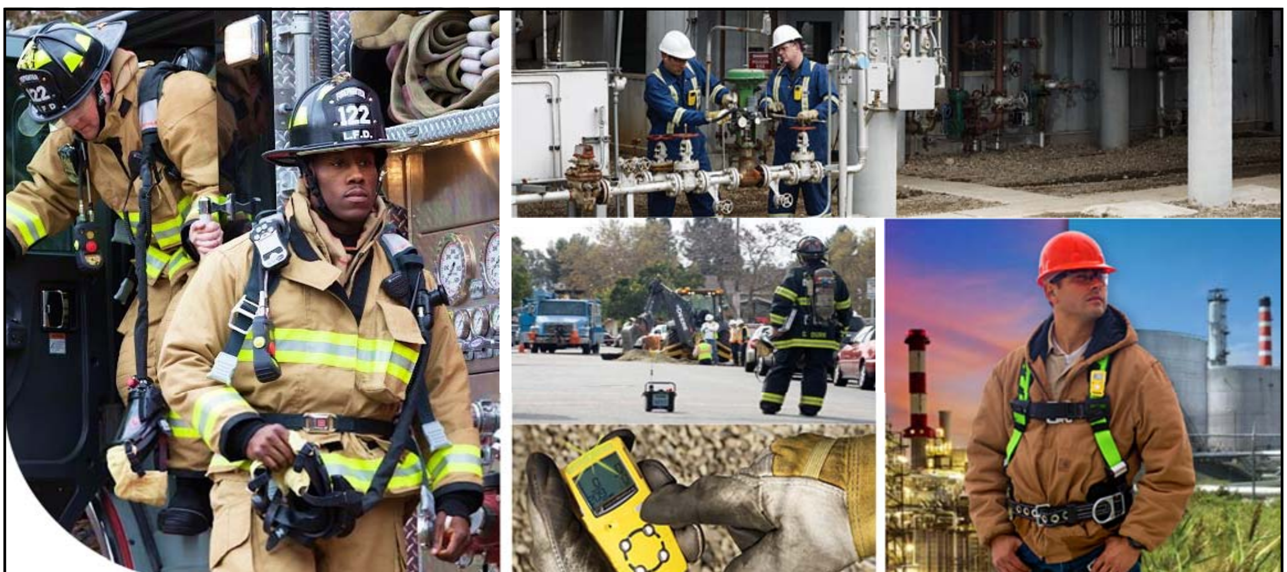
Toxic Effects H_2S

Concentration (ppm)	Symptoms
2 to 5	Nausea, tearing, headaches
20	Possible fatigue, loss of appetite, headache, dizziness
50 to 100	Conjunctivitis, respiratory tract irritation in 1 hour
100	IDLH concentration – CDC NIOSH Pocket Guide to Chemical Hazards
100 to 150	Coughing, eye irritation, olfactory fatigue, shortness of breath, severe symptoms after prolonged exposure >2 hours
200 to 300	Severe conjunctivitis, respiratory tract irritation, pulmonary edema from prolonged exposure >1 hour
500 to 700	Loss of mobility, collapse in 5 minutes, serious eye damage within 30 minutes, death in <60 minutes
700 to 1,000	Rapid incapacitation, cessation of breathing, death within minutes

Effects may vary by individual

Other Detectable Toxic Gases

Gas Name	Molecular Formula	Molecular Weight (g/mol)	Characteristics
Sulphur dioxide	SO_2	64.1	Colourless, struck match odour
Chlorine	Cl_2	70.9	Greenish-yellow, strong distinctive odour – household bleach
Ammonia	NH_3	17.0	Colourless, characteristic pungent odour
Nitrogen dioxide	NO_2	46.1	Reddish-brown, sharp biting odour
Hydrogen cyanide	HCN	28.01	Very pale blue or colourless, oil of bitter almond odour
Nitric oxide	NO	30.0	Colourless, radical molecule, when exposed to air rapidly becomes NO_2
Chlorine dioxide	ClO_2	67.5	Yellow to reddish, acrid odour
Phosphine	PH_3	34.0	Colourless, garlic or rotting fish odour
Ethylene oxide (ETO)	C_2H_4O	44.1	Colourless, faintly sweet odour
Ozone	O_3	48.0	Pale blue, distinctively pungent odour



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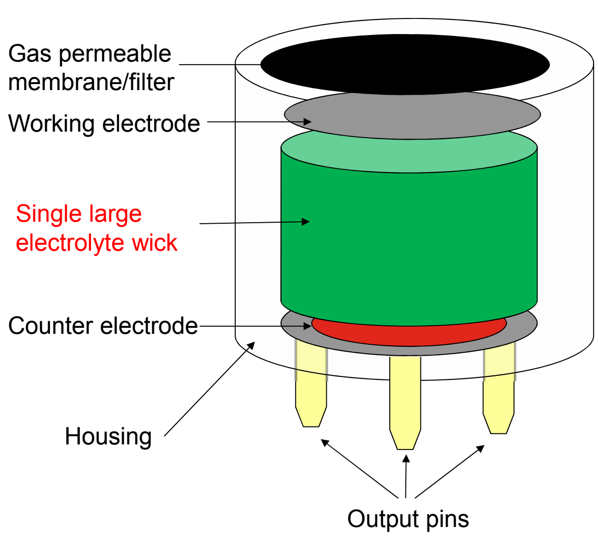
AT THE HEART OF GAS DETECTION
Electrochemical toxic gas sensors

Gas Specific Electrochemical Sensors

- Gas diffusing into sensor reacts at surface of the sensing electrode
- Sensing electrode made to catalyze a specific reaction
- Use of selective external filters further limits cross sensitivity

Typical Electrochemical Sensor Design



- ***How does it work?*** *Chemical reaction generates electrical current*
- ***Why Do We Use It?***
  - *No Mechanical Parts*
  - *Linear response to gas concentrations*
  - *Generally reliable and economical*
- ***Challenges***
  - *Sensitive to temp and humidity extremes*
  - *Speed of response*
  - *Cross sensitivity*
  - *CO2 sensor requires constant bias*

CO and H_2S Sensor Detection Mechanism

Carbon monoxide is oxidized at the sensing electrode:

$CO + H_2O \rightarrow CO_2 + 2H^+ + 2e^-$

The counter electrode acts to balance out the reaction at the sensing electrode by reducing oxygen present in the air to water:

$1/2O_2 + 2H^+ + 2e^- \rightarrow H_2O$

And the overall reaction is: $CO + ½O_2 \rightarrow CO_2$

4CF Signal Output: 0.07 µ A / ppm CO

Hydrogen sulphide is oxidized at the sensing electrode:

$H_2S + 4H_2O \rightarrow H_2SO_4 + 8H^+ + 8e^-$

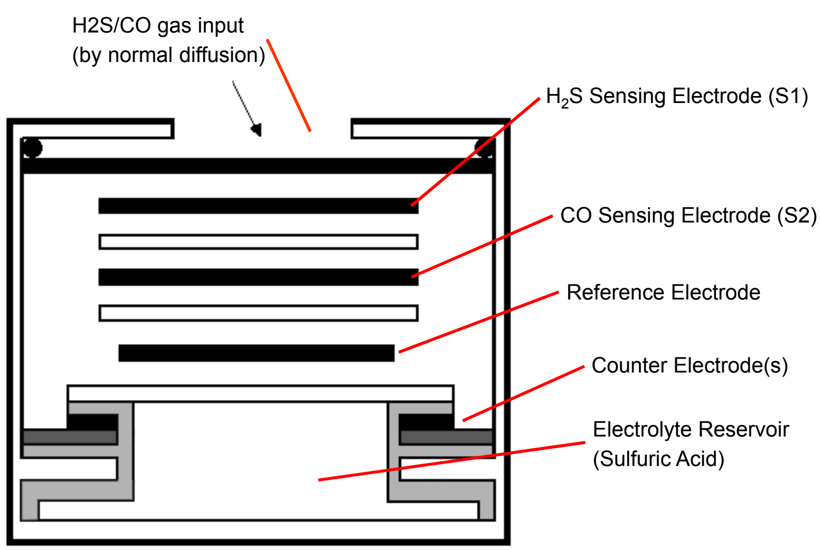
The counter electrode acts to balance out the reaction at the sensing electrode by reducing oxygen present in the air to water:

$2O_2 + 8H^+ + 8e^- \rightarrow 4H_2O$

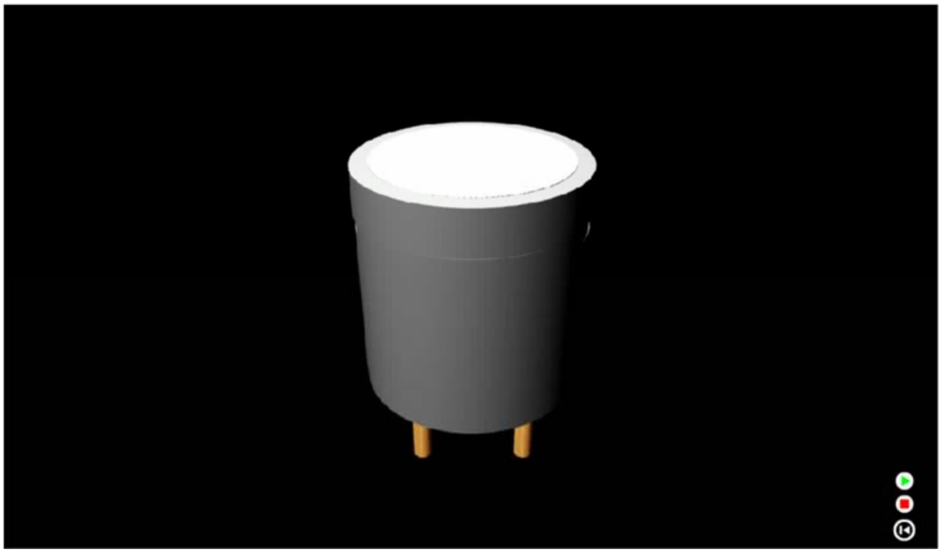
And the overall reaction is: $H_2S + 2O_2 \rightarrow H_2$ SO4

4HS Signal Output: 0.7 µ A / ppm H_2S

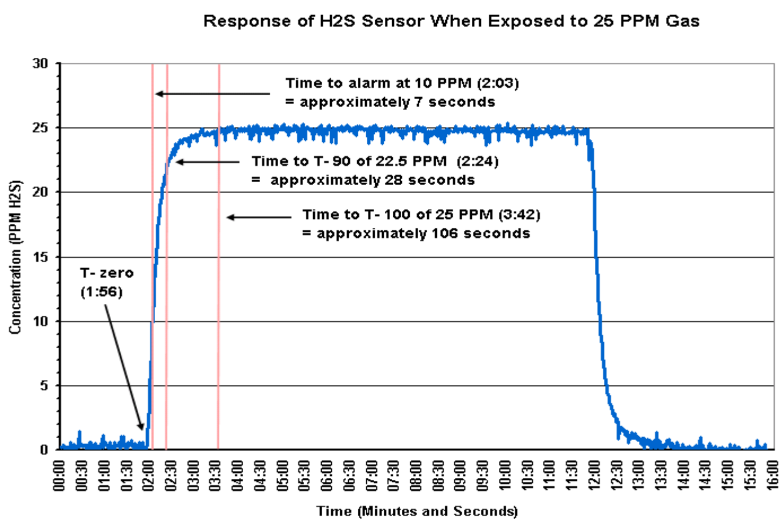
COSH Sensor

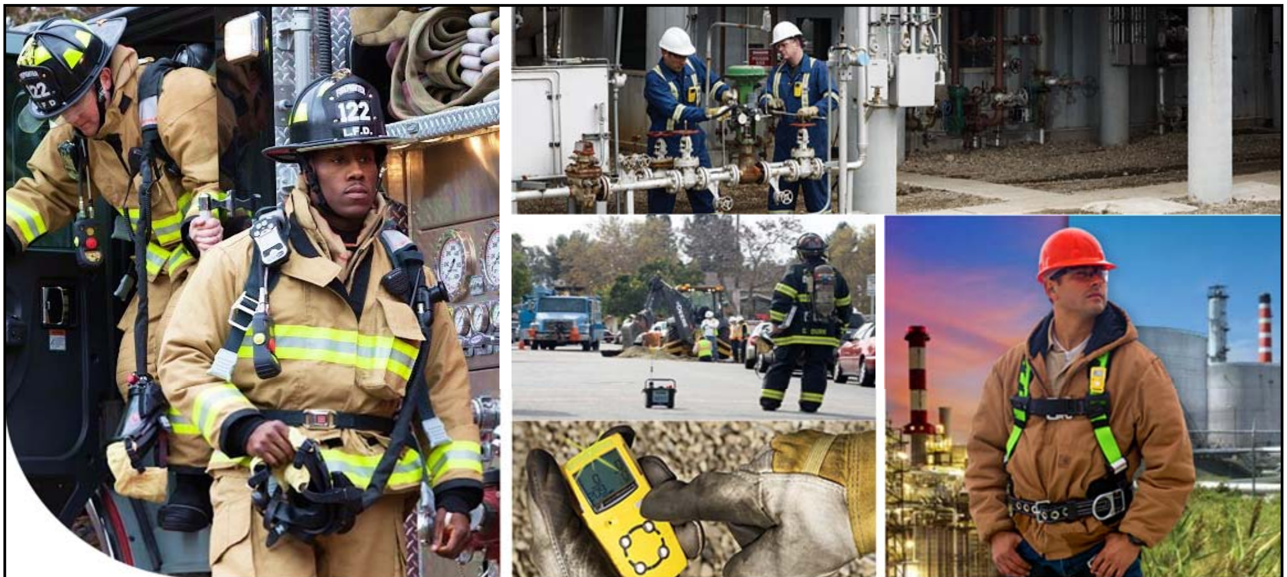


COSH Sensor



What is T90 Response?





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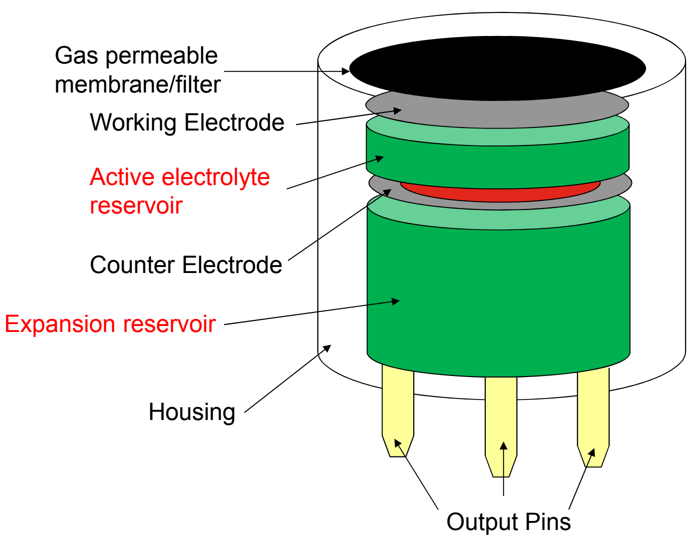
AT THE HEART OF GAS DETECTION

Honeywell exclusive Surecell sensor technology

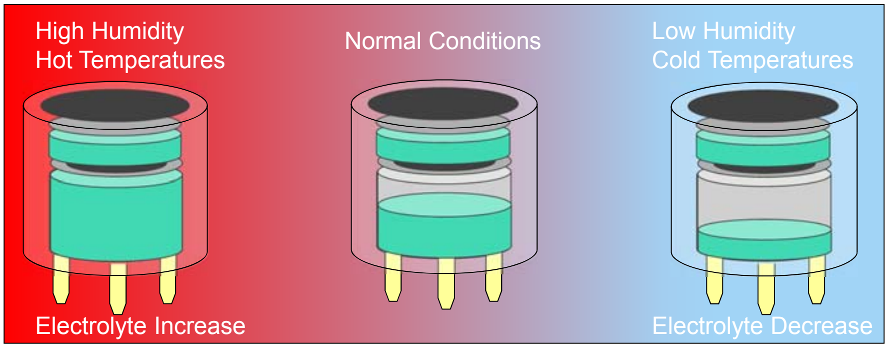
Honeywell SureCell electrochemical design



Advantages

- Separate electrolyte reservoirs allow for expansion and contraction under extreme conditions
- Faster speed of response
- Better linearity
- Longer calibration intervals

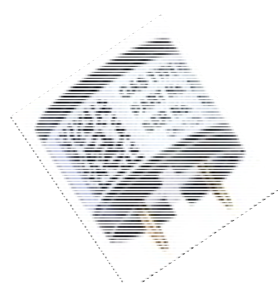
SureCell Sensor Advantage



- Prevents cell bursting/leakage in high temperature and humidity environments
- Prevents dehydration in low temperature & humidity environments
- Produces faster and more reproducible response times
- Decreases warm-up time
- Reduced Cross interference's to VOCs

The Reflex™ Advantage

- **Reflex™** is a Honeywell Analytics patented electronic circuit fault diagnostic routine for electrochemical cells
- **Reflex™** increases operator confidence
- **Reflex™** continuously checks sensor health:
  - On detector power up
  - During operation of the detector
- **Reflex™** checks for:
  - Cell presence
  - Cell dry out
  - Cell open circuit and cell short circuit



- **Note: Not relevant for NO, ETO and O_2 electrochemical sensors. Does not remove the need for regular bump testing or calibration.**

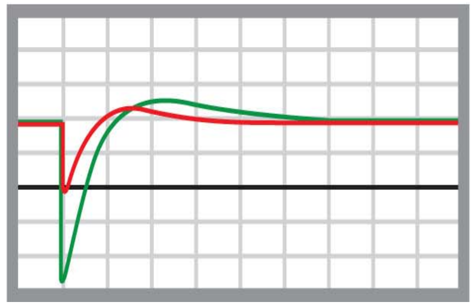
The Reflex™ Advantage

Reflex® Keeps You Safer

Oscilloscope graph shows cell responding to Reflex pulse, indicating sensor condition.

GREEN shows optimal sensor condition (dynamic responsiveness to gas).

RED shows degraded sensor condition (indicating cell dry-out or failure).



Electrochemical Sensor Cross Sensitivity

Gas	Carbon Monoxide (CO)	Hydrogen Sulfide (H_2S)	Sulfur Dioxide (SO_2)	Chlorine (Cl_2)	Hydrogen Cyanide (HCN)
CO	100	< 1	< 1	0	0
H_2S	< 5	100	0	0	0
SO_2	< 10	20	100	8	8
NO	< 10	< 2	0	0	0
NO_2	+/- 5	- 20	- 100	20	- 5
Cl_2	0	ND	< 5	100	- 70
H_2	< 40	< 1	0	0	0
HCN	ND	ND	ND	0	ND
HCl	ND	ND	0	0	ND
NH_3	0	0	0	0	0
C_2H_4	< 50	0	ND	0	0

* Cross sensitivity data is intended for guidance only. Actual response may vary. ND = No Data

Cross Sensitivity Can Be a Blessing

Example:

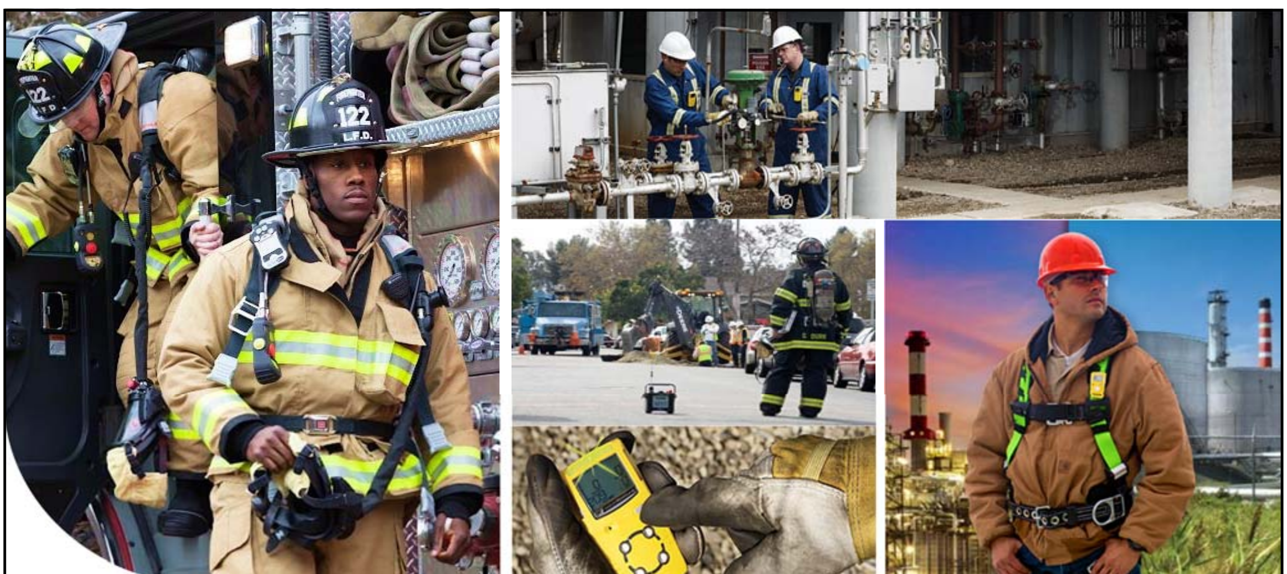
- A Florida power plant was recommissioning a hydrogen generator following a plant shutdown
- While filling the generator an operator noticed the H_2 pressure decreasing
- the operator called the plant safety officer to notify they were getting a CO alarm condition on their GasAlertMicro 5 detector
- the plant safety officer brought out another GasAlertMicro 5 - the CO sensor readings overloaded and the LEL reading indicated 15% - they were confused by the high CO readings combined with the LEL readings when there was no suspected CO present
- the safety officer barricaded the area and called BW to find out what could be causing the readings on the CO sensor if no CO is present and the first suggestion was H_2 - many CO sensors exhibit a cross sensitivity to H_2 and the fact the LEL sensor responded substantiated H_2
- the customer went back with the GasAlertMicro 5 and found a H_2 leak in the generator where the detector was getting the highest readings
- They were able to repair the leak and were very thankful for the technical assistance
- This cross sensitive response of the CO sensor helped prevent a possible explosion that may have resulted in loss of life and loss of property

Those Annoying Alarms!

- Alcohols and citrus solvents can have a profound effect on some electrochemical sensors – CO and H_2S for example
- Orange peels contain d-limonene, the same "citrus oil" solvent included in many household cleaners
- alcohols can be found in many workplace situations – for example, in northern climates during winter months methanol is often used to de-ice valves and fittings; biofuel plants produce ethanol from corn
- H_2S, CO and COSH sensors can exhibit a profound response to d-limonene and alcohols such as methanol
- Instrument responds by going into alarm, making this a "Fail Safe" alarm condition
- The d-limonene and alcohol molecules can take considerable time to dissipate from the sensor electrolyte causing an alarm condition that can go on for hours, even days
- Good news is the sensor will eventually recover baseline and in most cases still operates normally – once the sensor has recovered be sure to test it's function

Some Toxic Sensor Considerations

- Background concentrations of NH_3 can shorten the life of the NH_3 sensor
- For calibration of O_3 and ClO_2 an appropriate generator must be used; gas generators are not compatible with MicroDock II system; Cl_2 is commonly used to bump test ClO_2 and O_3.
- The sensor port hydrophobic filter will impair the diffusion of O_3 molecules so this sensor is unfiltered on purpose
- Chlorine: Chlorine is a “sticky” gas and requires a 1LPM regulator for calibration, and can only be bumped not calibrated in the MicroDockII
- Some toxic sensor combinations are not compatible – for unusual requests consult the manufacturer



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VOLATILE ORGANIC COMPOUNDS

Increased awareness = Increased detection

VOC Toxicity

- Toxic substances can present as acute and/or chronic human health hazards
- While some VOCs are acutely toxic at low concentrations, most VOCs are chronically toxic
- Because of the long-term nature of physiological effects of many VOCs the tendency has been to overlook the presence in workplace atmospheres
- Exposure typically occurs via skin or eye contact with liquids or aerosol droplets, or inhalation of vapours
- Most have surprisingly low occupational exposure limits
- VOCs present multiple potential health threats in the workplace environment
- Dedicated PID instruments generally the best choice for industrial hygiene measurement of VOCs at exposure limit concentrations
- PID technology is typically suitable for those combustible liquids with Flash Points >37.8°C (100°F)

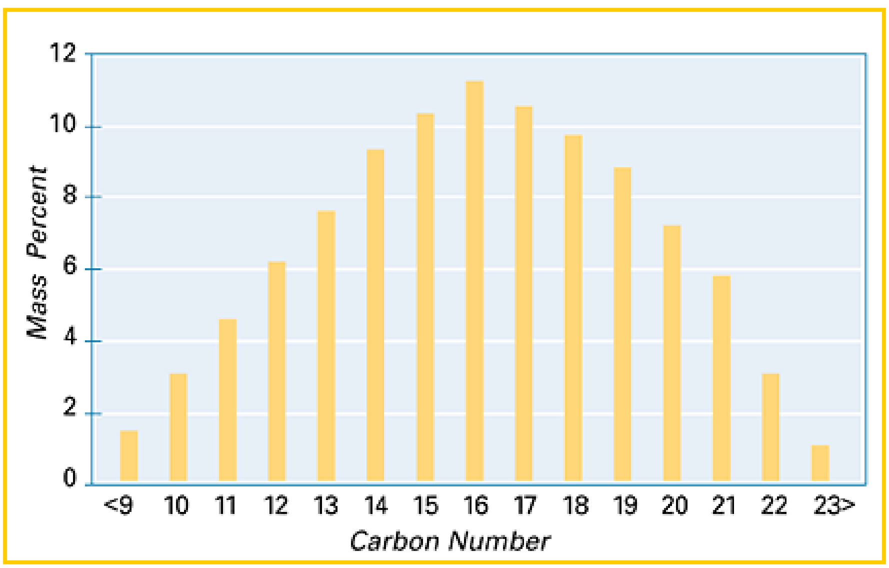
VOCs and LEL

- Many VOC vapours have surprisingly low LEL concentrations:
  - For jet fuel 100% LEL = 0.7% v/v (7,000 ppm)
  - By comparison, LEL concentration for methane = 5% v/v (50,000 PPM)
- Tendency in the past has been to measure them by means of percent LEL combustible gas instruments
- Combustible gas instrument alarms usually set to 5% or 10% LEL
- Unfortunately, most VOC vapours are also toxic, with Threshold Limit Values (TLV) values much lower than the 5% or 10% LEL
- In many applications the toxic exposure is exceeded long before the LEL sensor will indicate a reading

Combustible Sensor Limitations

Contaminant	LEL (Vol %)	Flashpoint Temp (ºF)	OSHA PEL	NIOSH REL	TLV	5% LEL in PPM
Acetone	2.50%	-4ºF (-20 ºC)	1,000 PPM TWA	250 PPM TWA	500 PPM TWA 750 PPM STEL	1250 PPM
Diesel (No.2) vapor	0.60%	125ºF (51.7ºC)	None Listed	None Listed	15 PPM	300 PPM
Ethanol	3.30%	55ºF (12.8 ºC)	1,000 PPM TWA	1000 PPM TWA	1000 PPM TWA	1,650 PPM
Gasoline	1.30%	-50ºF (-45.6ºC)	None Listed	None Listed	300 PPM TWA 500 PPM STEL	650 PPM
Hexane	1.10%	-7ºF (-21.7 ºC)	500 PPM TWA	50 PPM TWA	50 PPM TWA	550 PPM
Isopropyl alcohol	2.00%	53ºF (11.7ºC)	400 PPM TWA	400 PPM TWA 500 PPM STEL	200 PPM TWA 400 PPM STEL	1000 PPM
Kerosene/Jet Fuels	0.70%	100 – 162ºF (37.8 – 72.3ºC)	None Listed	100 mg/M3 TWA (approx 14.4 PPM)	200 mg/M3 TWA (approx 29 PPM)	350 PPM
MEK	1.40%	16ºF (-8.9ºC)	200 PPM TWA	200 PPM TWA 300 PPM STEL	200 PPM TWA 300 PPM STEL	700 PPM
Turpentine	0.8%	95ºF (35ºC)	100 PPM TWA	100 PPM TWA	20 PPM TWA	400 PPM
Xylenes (o, m & p isomers)	0.9 – 1.1%	81 – 90ºF (27.3 – 32.3 ºC)	100 PPM TWA	100 PPM TWA 50 PPM STEL	100 PPM TWA 150 PPM STEL	450 – 550 PPM

Typical Composition of No. 2 Diesel Fuel



Limitations of LEL Sensor

- Percent LEL sensors have poor sensitivity to the large molecules found in fuels, solvents and other VOCs, with flashpoint temperatures higher than 37.8ºC (100ºF)
- Percent LEL detectors are poor indicators for the presence of many VOCs, but lack of a reading may not provide proof whether a hazard is present
- Reliance on catalytic bead combustible gas sensors for measurement of VOC vapours can give a false sense of protection - the catalytic bead sensor technology may exhibit limited, or no, response to the target gas hazard; human toxicity levels may be exceeded long before the combustible sensor is capable of providing readings

LEL vs. PID Sensors

- Catalytic hot-bead combustible sensors and photoionization detectors complementary detection techniques
- Catalytic hot-bead sensors excellent for measurement of methane, propane, and other common combustible gases that may NOT be detectable by PID
- PIDs detect large VOC and hydrocarbon molecules that are undetectable by hot-bead sensors
- Best approach to VOC measurement for many applications is a multi-sensor instrument capable of measuring all the atmospheric hazards that may be potentially present

Typical PID Applications

PID provides broad range detection for multiple applications:

- Rapid screening technique for initial area hazard assessment
- HAZMAT Response teams
- Monitoring and data acquisition of human exposures in the workplace
- Environmental consulting/assesment – soil remediation
- Aircraft wing tank entry
- Detection of aviation fuel vapours
- Detection of diesel fuel vapours
- Additional level of broad band detection of VOCs that may be encountered in confined space entry
- Building management companies for screening "bad" air complaints from tenants

Non-Specific Sensing Technology

- VOCs usually detected by means of broad range sensors
- Broad range sensors provide overall reading for general class or group of chemically related contaminants
- Cannot distinguish between different contaminants they are able to detect
- Provide one total reading for all detectable substances present

PID Benefits:

- Relatively low cost detection of a wide range of toxic VOCs
- Sensitive to PPM levels – be aware of the lowest detectable limit capability
- Accurate and linear over sensor detection range; but readings are relative to the gas used for calibration

Response is Relative to Calibration Gas

- Reading of 10 ppm indicates ion current relevant to that produced by a 10 ppm concentration of the calibration gas – typically isobutylene
- Amount of different contaminant needed to produce same current may be larger or smaller than concentration of calibration gas
- Since PID readings are always relative to a calibration gas, readings should actually be recorded as ppm-calibration gas equivalent units, or PID units, never as actual concentrations unless:
  - Contaminant being monitored is same as one used to calibrate instrument, or;
  - Reading is corrected to account for difference in relative response

PID Readings

- PID allows quantified readings only when substance measured is known
- If substance is known, readings can be quantifiable to ppm resolution
- If substance unknown, readings should be expressed as "Isobutylene" or "PID" units
- CF should not be used unless and until a specific contaminant is identified

What About Benzene?

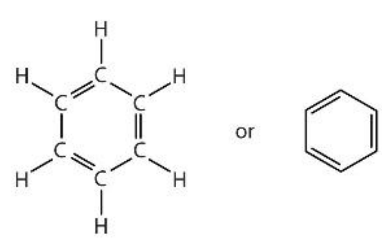
- Benzene is almost never present as a solitary molecule in nature
- Benzene is usually a minor fraction of the total VOC present
- ACGIH TLV = 0.5 ppm; OSHA PEL = 1.0 ppm – GasAlertMicro 5 PID is not able to detect at levels of concern
- GasAlertMicro 5 PID is capable of testing for total hydrocarbons (TVOC) – suitable for the detection of compounds such as:
  - Diesel 15 ppm
  - Kerosene 30 ppm
  - Jet Fuel (JP-8) 30 ppm
  - Gasoline 300 ppm

3000 Series PID

UltraRAE 3000

MultiRAE Benzene

- 9.8 eV PID lamp to narrow measurement spectrum
- RAE-Sep tube to isolate benzene molecule
- UltraRAE 3000 capable of producing STEL benzene measurement
- MultiRAE Benzene provides multi-gas capability



C_6H_6 - benzene

Decision Making with a PID

- **Two sensitivities must be understood to make a decision with a PID**
  - Human Sensitivity: as defined by AGCIH, NIOSH, OSHA or corporate exposure limits
  - PID Sensitivity: as defined through testing by the manufacturer of the PID

Additional Considerations

- Is the compound detectable?
- If it is detectable what is the TLV?
- What is the LDL of the PID sensor?

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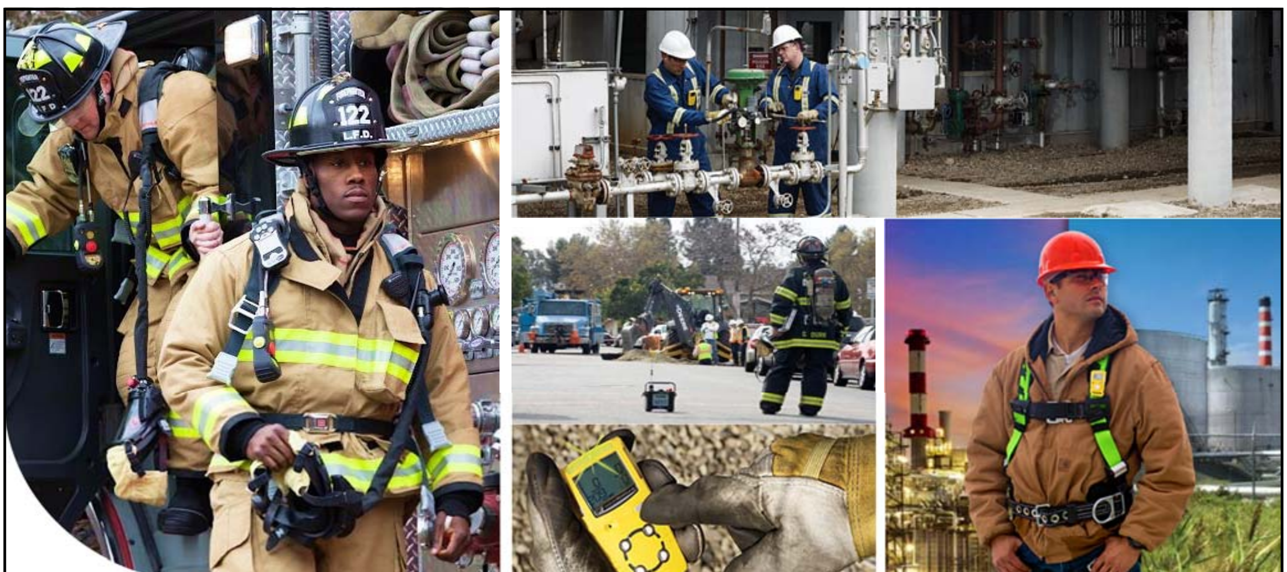

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AT THE HEART OF GAS DETECTION
PID sensor technology

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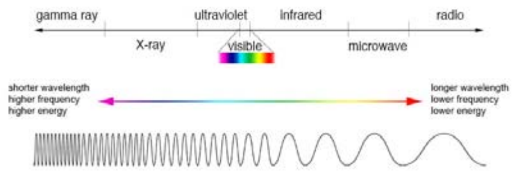
Photoionizaton Detector – PID basics

- A PID uses Ultraviolet (UV) energy to break down gas molecules to positive and negative ions (ionization) that can be counted by a detector.



Electromagnetic Spectrum

- A gas molecule absorbs the UV energy which excites the molecule causing temporary loss of a negatively charged electron creating a positively charged ion. UV radiation energy levels are commonly quantified in terms of electron volts, typically expressed as eV
- These ions produce a current that is amplified and indicated as a proportional number on the detector display.
- After passing through the PID sensor the ions recombine to form the original molecule.

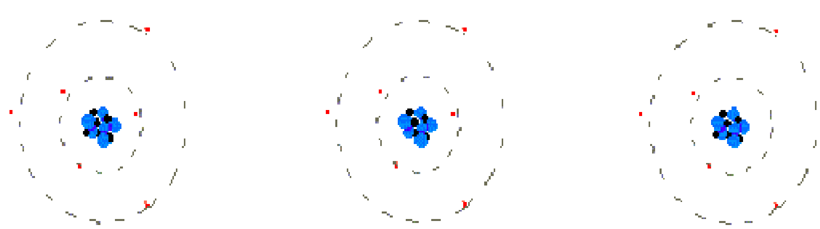
Photoionizaton Detector – PID basics

An ion is a charged atom or molecule.

This Atom is Neutral
Same number of protons and electrons

This Atom is Negatively Charged
More electrons than protons

This Atom is Positively Charged
More protons than electrons

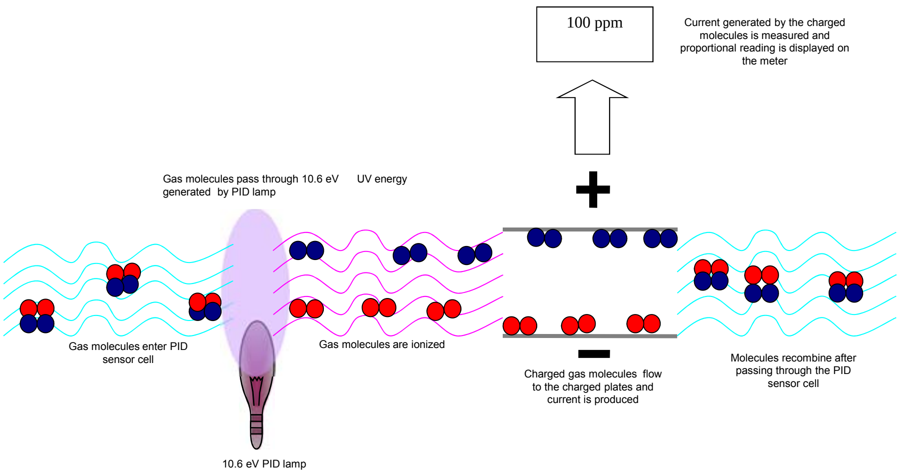


- 6 Protons
- 6 Neutrons
- 6 Electrons

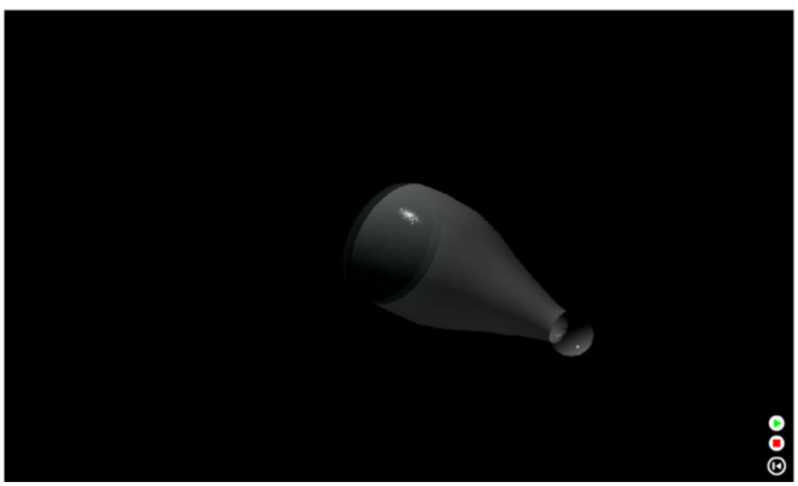
- 5 Protons
- 6 Neutrons
- 6 Electrons

- 6 Protons
- 6 Neutrons
- 5 Electrons

Photoionizaton Detector – PID basics



How does a PID work?



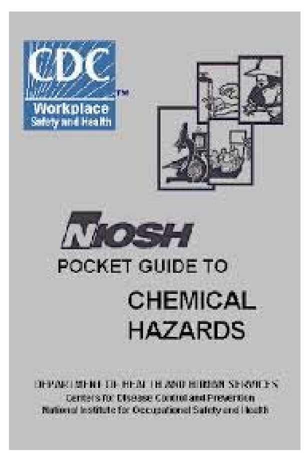
Ultraviolet energy is used to remove electron (ionize) from neutrally charged target molecules creating electrically charged fragments (ions)

Photoionizaton Detector – PID basics

- Detects hundreds of compounds – the PID sensor readings reflect the Total of all detectable Volatile Organic Compounds (VOCs) in the atmosphere being monitored
- The Ionization Potential of the target gas molecule must be less than the UV energy generated by the PID lamp: 10.6 eV
- Sensitive to ppm resolution
- Limitations:
  - non-specific sensing technology; the detector cannot identify the species of gas being detected
  - some routine maintenance recommended
  - be aware of the detector’s lowest detectable limit and human exposure limits for the target substance
  - Excessive moisture accumulation in the sensor can create false positive readings

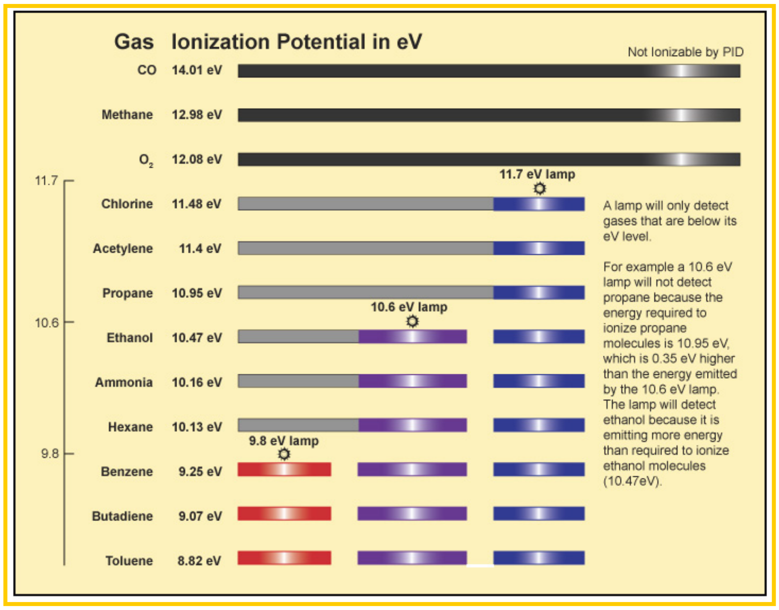
Photoionizaton Detector – PID basics

- Ionization Potential (IP) refers to the bond strength of a molecule – the molecules energy to hold outer shell electrons
- Ionization Potential for various gases can be found in the NIOSH Pocket Guide; among other chemistry texts
- IP is sometimes referred to as IE (Ionization Energy)
- If the IP of the gas is less than the energy output of the lamp (10.6 eV) the PID can detect the gas



http://www.cdc.gov/niosh/npg/

Photoionizaton Detector – PID basics



PID Detection Capabilities

Common Gases Detectable by PID

- Hydrocarbons with chemical names ending in –ane; -ene; -yne; EXCEPT methane and ethane
- Alcohols – compound with chemical names ending in –ol
- Aldehydes – compounds with chemical names ending in –aldehyde
- Ketones – compounds with chemical names ending in –one
- Esters – compounds with chemical names ending in -ate

PID Detection Capabilities

NOT Detectable by PID

- Gases in Fresh Air (N_2; O_2; CO_2)
- Natural Gas – CH_4; C_2H_6
- Acid Gases – HCl; HF
- Compounds not in gas phase, eg: H_2SO_4; HNO_3

PID Correction Factors

- Correction Factor (CF) provides an indication of PID sensitivity to a specific gas
- CFs do not make the PID measurement specific to a chemical, only corrects the measurement scale to that chemical based on empirical sensitivity testing
- CFs allow calibration using inexpensive, non-toxic “surrogate” gas (typically isobutylene)
- Most manufacturers furnish tables, or include an integral PID detector CF library of gases to correct or normalize readings when contaminant is known
- PID detectors are capable of providing readings in parts per million equivalent concentrations for the contaminant measured
  - It is important to fully understand the use of corrections factors if implementing in your gas detection safety program.

CF Indicates Sensitivity

- **Low CF = high PID sensitivity to a gas**
- **More toxic the gas, more desirable to have low correction factor :**
  - If Human Exposure limit is < 10 ppm, CF should be ≤ 1
- **If chemical less toxic, higher CF may be acceptable**
  - If Human Exposure limit is > 10 ppm, CF ≤ 10
- **When CF > 10 use PIDs as gross leak detectors only**
  - High correction factor amplifies effects of interfering gases and vapors

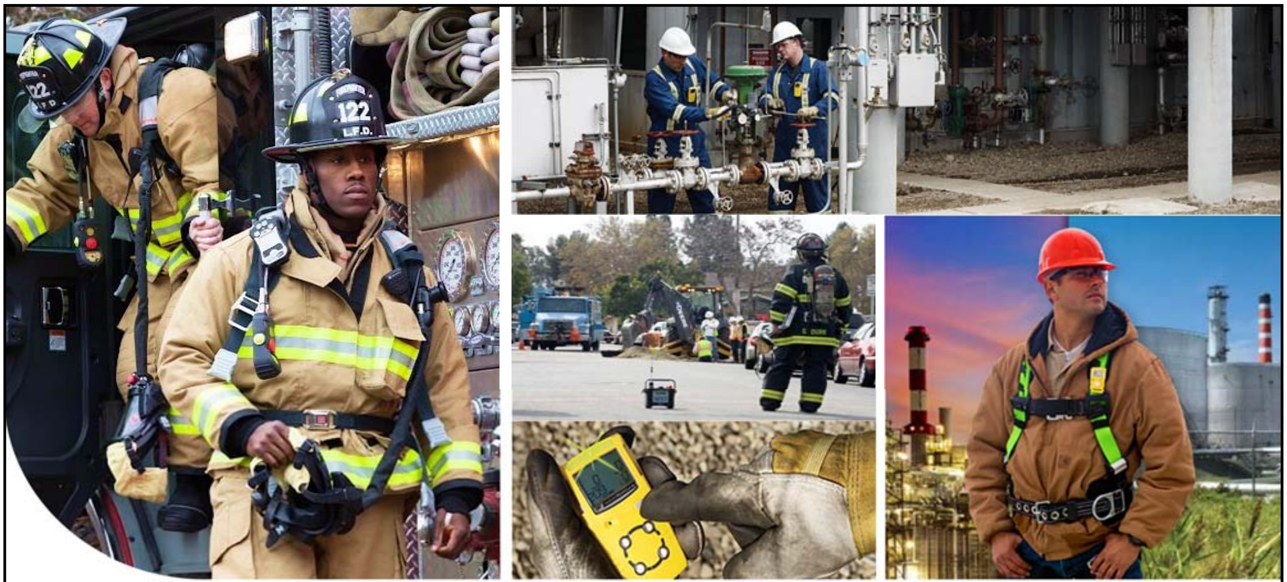
Correction Factors

Lamp characteristics can vary from one manufacturer to the next – use Correction Factors from the manufacturer of the PID device.

10.6 eV Lamp Correction Factors

	RAE	BW	ION		RAE	BW	ION
Acetaldehyde	6.0	4.6	5.5	Jet fuel (JP-8)	0.94	0.6	0.7
Acetone	0.9	1.2	1.17	Methane	NR	NR	NR
Ammonia	10.9	10.6	8.5	Methyl ethyl ketone	1.0	0.9	0.96
Benzene	0.47	0.5	0.53	Napthalene	0.42	0.5	0.4
Butadiene	0.6	0.9	0.8	Styrene	0.43	0.5	0.45
Diesel fuel #2	0.7	0.9	0.8	Toluene	0.45	0.5	0.56
Ethanol	9.6	13.3	11.0	Turpentine	0.4	0.45	0.6
Ethylene glycol	16.0	17.0	9.0	Vinyl chloride	2.0	2	2.1
Gasoline #1	0.9	0.7	0.9	Xylene, m-	0.44	0.5	0.5
n-Hexane	4.3	4.6	3.0				

RAE TN-106 01/16/VK; BW CF List 2016 January 06 Rev. 3; ion SCIENCE Version 1.8, 15 March 2017, WRJ/FD



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CARBON DIOXIDE

It's in the air we breathe; what's the hazard?

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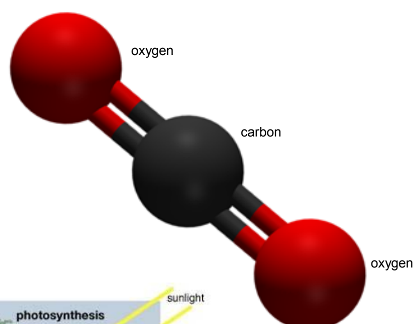
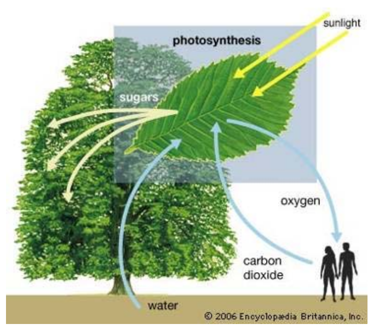
Carbon Dioxide

Molecular formula: CO_2
Molecular weight: 44.01 g/mol
Non-flammable
Characteristics: colourless, odourless
Naturally occurring chemical compound present as a trace gas in the earth's atmosphere at an average concentration of approximately 400 ppm

Sources of CO_2:

- Anthropogenic creation primarily through the burning of fossil fuels
- Fermentation processes
- Dry ice inertion
- CO_2 injection for enhanced oil recovery
- Beverage carbonation





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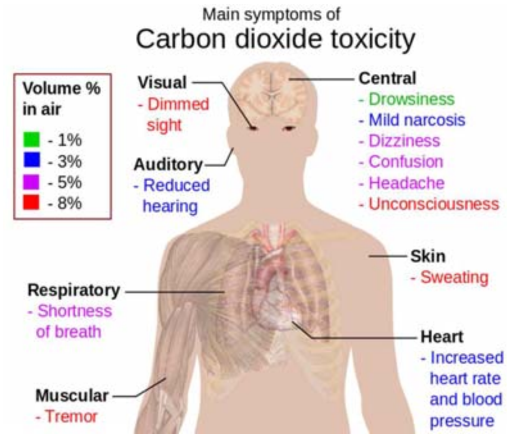
Carbon Dioxide

Symptoms of exposure:

- drowsiness
- Rapid or irregular pulse rate
- Headaches
- Dizziness
- Disorientation
- Asphyxiation
- Death



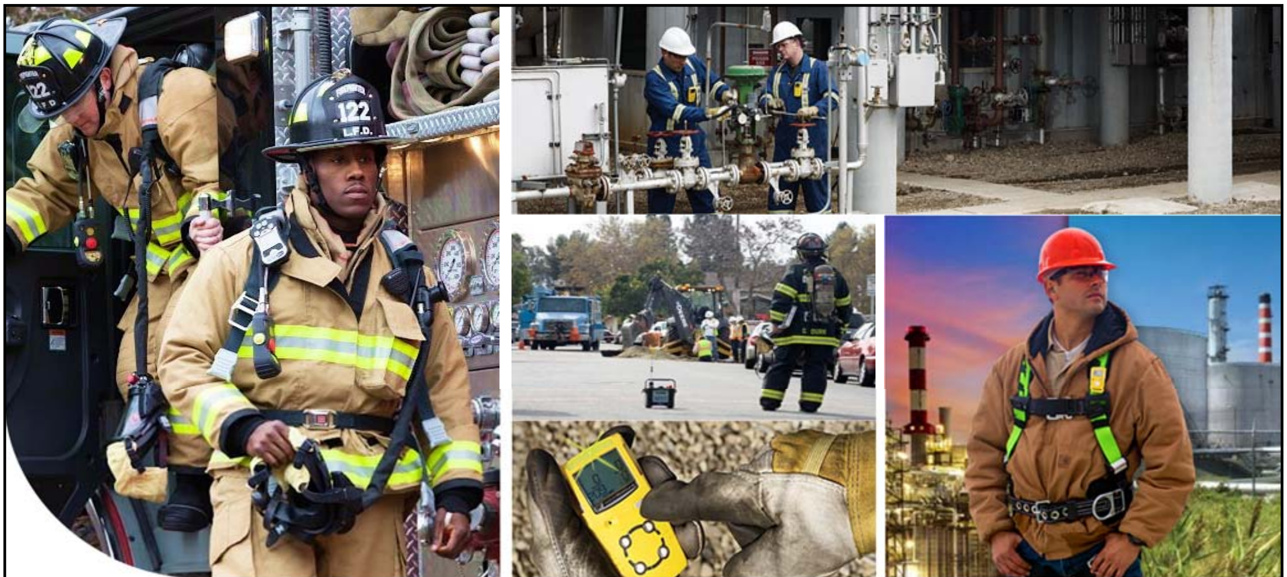
Physiological effects:

- Carbon dioxide enters the body through inhalation. Once in the lungs the gas molecules pass through capillaries to the blood stream. Normally there is a higher concentration of CO_2 in the blood than in the lungs so that when the gas exchange occurs at the alveoli the lungs are able to exhale CO_2. Elevated CO_2 concentration in the lungs cause respiratory acidosis (pH change) and disrupts normal respiration. The body experiences oxygen depletion as a result of the increased CO_2 levels which can result in death.

Toxic Effects CO_2

Concentration (% v/v)	Symptoms
0.1 to 0.2	Drowsiness, loss of concentration
2 to 3	Shortness of breath, deep breathing
4	IDLH concentration – CDC NIOSH Pocket Guide to Chemical Hazards
5	Breathing becomes heavy, perspiration, rapid pulse
7.5	Headache, dizziness, severe shortness of breath, increased heart rate and blood pressure, visual distortion
10	Impaired hearing, nausea, vomiting, loss of conciousness
30	Coma, convulsions, death

Effects may vary by individual



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AT THE HEART OF GAS DETECTION

NDIR CO_2 Sensor

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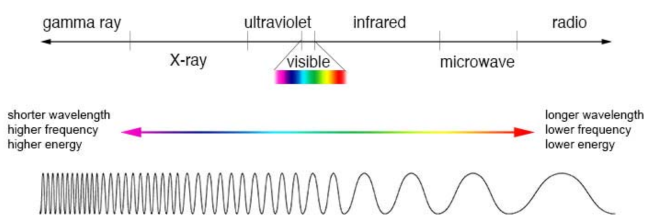
NDIR Sensor

- Chemical bonds absorb infrared radiation
- For infrared energy to be absorbed (that is, for vibrational energy to be transferred to the molecule), the frequency must match the frequency of the mode of vibration
- Specific molecules absorb infrared radiation at precise frequencies
- When infrared radiation passes through a sensing chamber containing a specific contaminant, only those frequencies that match one of the vibration modes are absorbed
- The rest of the light is transmitted through the chamber without hindrance
- The presence of a particular chemical group within a molecule thus gives rise to characteristic absorption bands



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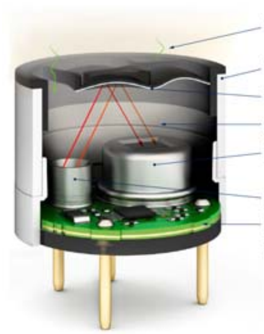
NDIR Sensor

NDIR sensor consists of:

- Infrared emitter
- Optical filters that limit IR source to specific infrared wavelength range
- Optical chamber
- photodetector (active and reference)

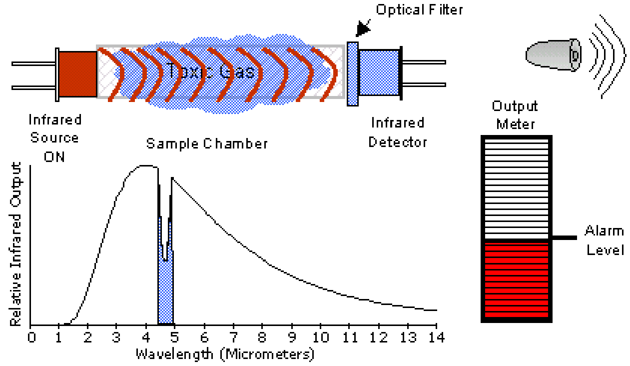


Non-dispersive Infrared Gas Sensors

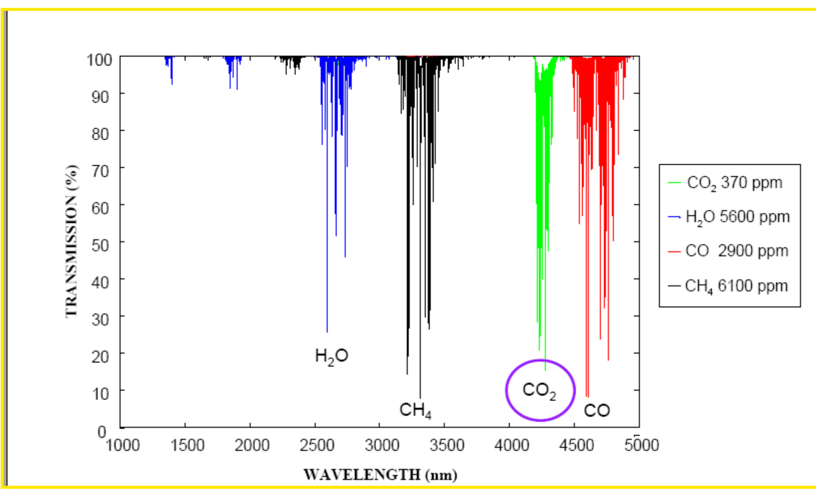
Carbon Dioxide

NDIR Sensor

NDIR detector measures absorbance at specific wavelength to determine concentration of target gas

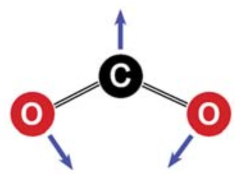


IR Energy Molecular Absorption



CO_2

- Infrared absorption of CO_2 molecules at a specific wavelength of 4.26 μm
- Sensor consists of IR source, light path, active detector and reference detector
- Concentration of CO_2 determines intensity of light striking active detector
- Reference detector provides a real-time signal to compensate the variation of light intensity due to ambient or sensor itself



Carbon dioxide molecule. The arrows show how the molecule vibrates when it absorbs energy.

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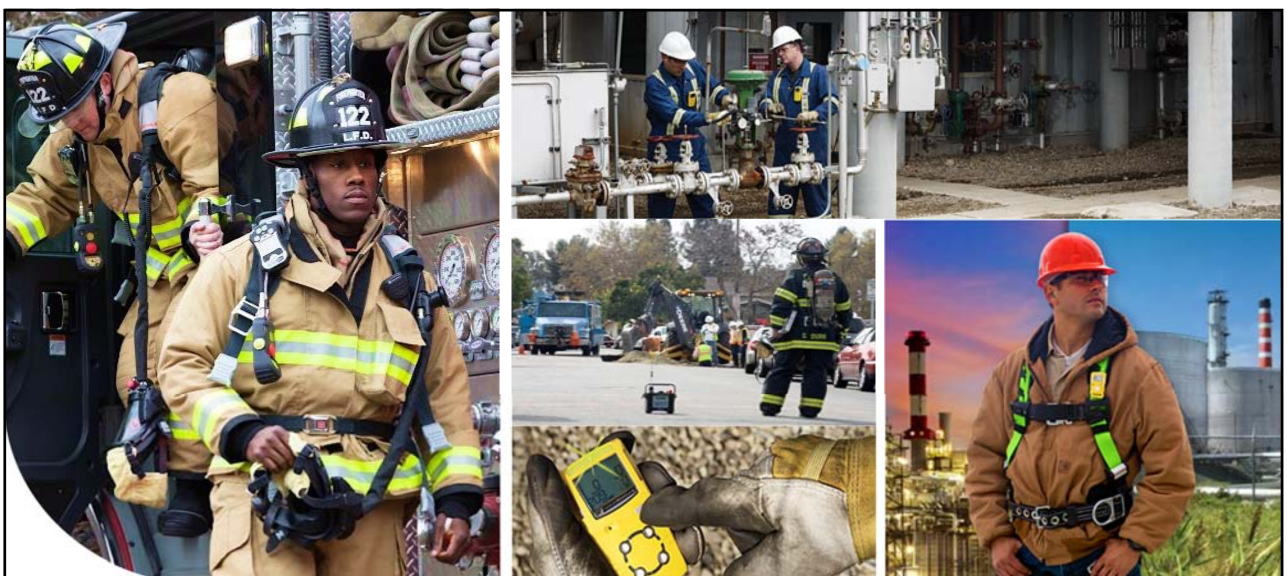

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AT THE HEART OF GAS DETECTION

NDIR combustible gas sensor

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Non-dispersive Infrared Gas Sensors

Combustible Gases

Ultra-low power consumption NDIR combustible gas sensor

Non-dispersive Infrared Gas Sensors

BW Clip4 – it's always on!

Ultra-low power consumption NDIR combustible gas sensor - BW Clip4 runs continuously once activated for 24 months without ever requiring a charge

NDIR Combustible Sensor Capabilities

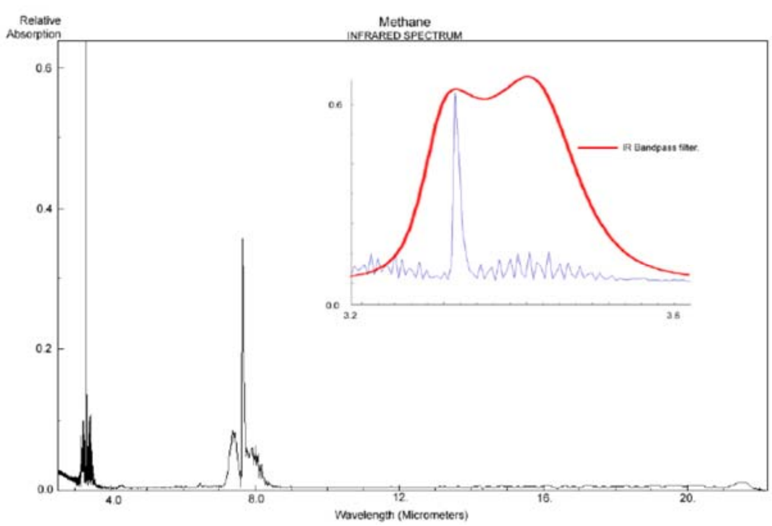
Can Detect (green)

Cannot Detect (red)

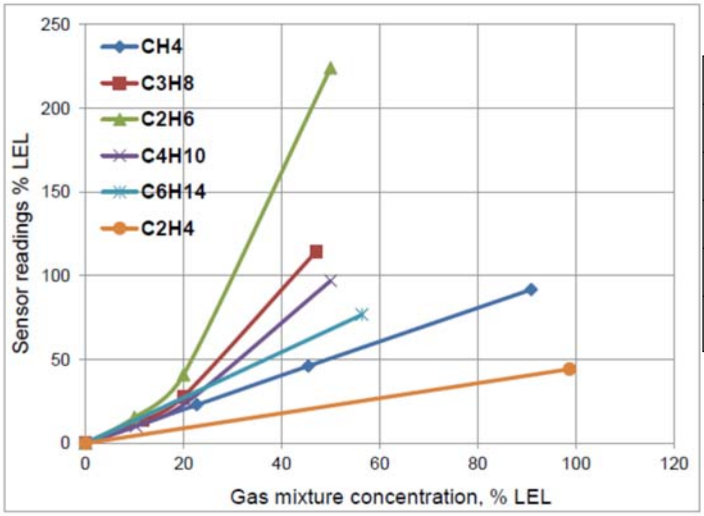
BW Clip4 (LED IR)	Combustible Gas	GasAlertMicroClip XL/X3 (Unfiltered Catalytic Bead)
Can Detect	Methane	Can Detect
Can Detect	Propane	Can Detect
Can Detect	Ethane	Can Detect
Can Detect	Butane	Can Detect
Can Detect	Hexane	Can Detect
Can Detect	Pentane	Can Detect
Can Detect	Methanol/Ethanol	Can Detect
Cannot Detect	Hydrogen	Can Detect
Can Detect	Cyclohexane	Can Detect
Cannot Detect	Acetylene	Can Detect
Can Detect	Ethylene	Can Detect

NDIR sensor technology is not capable of detecting diatomic homonuclear gas molecules, or gas molecules that absorb infrared energy outside of the IR detection bandwidth.

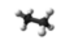
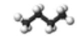
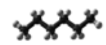
NDIR Combustible Gas Measurement



NDIR Combustible Gas Measurement



Typical sensor response to other hydrocarbons based on CH_4 calibration

Methane	CH_4	1 Carbon	
Propane	C_3H_8	3 Carbon	
Ethane	C_2H_6	2 Carbon	
Butane	C_4H_{10}	4 Carbon	
Hexane	C_6H_{14}	6 Carbon	
Ethylene	C_2H_4	2 Carbon	

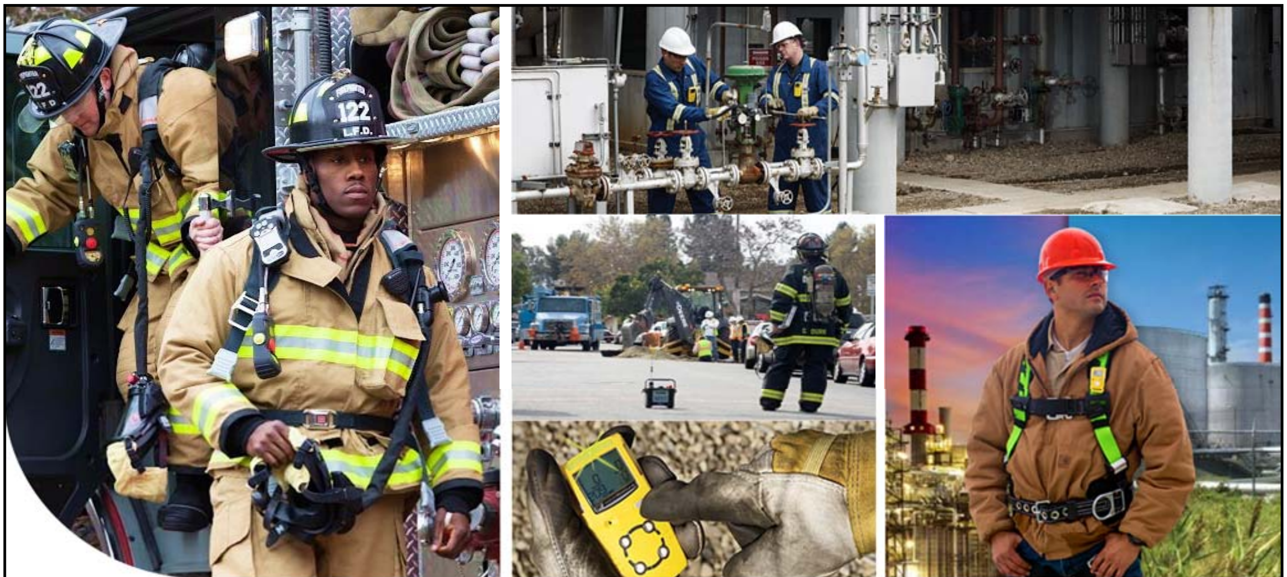
NDIR Combustible Gas Measurement

Advantages

- Does not require presence of O_2
- Not affected by poisons or inhibitors
- Lower power consumption than catalytic bead sensor
- Accuracy very stable
- Normally fails safe
- Sensor available for100% v/v CH_4
- 5 year MTBF - lower cost of ownership over lifespan

Limitations

- cannot detect **hydrogen**, **acetylene**, carbon disulphide,…
- High cost compared to catalytic bead sensor
- Affected more by changes in temperature and pressure.
- Response is linear to methane but non-linear to other hydrocarbons



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GAS DETECTION FUNDAMENTALS

Bump testing – calibration – record keeping

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Calibration, BUMP Testing and Verification

Calibration: The adjustment of sensor response accuracy to a known concentration of target gas.

Bump test: A qualitative test confirming sensor response to target gas and verification of alarm function

Calibration Verification: A quantitative test with a known concentration of target gas to confirm sensor response accuracy and verification of alarm function

DOCUMENT ALL TESTING……IF IT WASN'T DOCUMENTED IT DIDN'T HAPPEN

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Calibration and Bump Testing

- BW Technologies by Honeywell recommend calibrating prior to first time use and then at least every 180 days
- Bump test “direct reading” portable safety gas detectors prior to each day’s use at a minimum
- Calibrate if the portable safety gas detector fails a Bump test or Calibration Verification
- It does not harm the portable safety gas detection sensor(s) if calibration or Bump testing is done more frequently

Calibration and Bump Testing

So, is it dangerous to use a cylinder that contains 25 ppm H_2S?

34 liters = 1.2 cubic feet
10 X 10 X 10 room = 1,000 cubic feet
1.2 cubic feet = 0.12% of the volume of the entire room
25 ppm X .0012 = 0.03 ppm H_2S

In a 10 x 10 x 10 room 25 ppm H_2S dissipates to a concentration of 0.03 ppm

Substances that may affect sensors

Quick Reference Guide

Sensor Poisons and Contaminants

Several cleaners, solvents, and lubricants can contaminate and cause permanent damage to sensors. Before using cleaners, solvents, and lubricants in close proximity to the detector sensors, read and adhere to the following caution and table.

⚠ Caution

Use only the following BW Technologies by Honeywell recommended products and procedures:

- **Use water based cleaners.**
- **Use non-alcohol based cleaners.**
- **Clean the exterior with a soft, damp cloth.**
- **Do not use soaps, polishes, or solvents.**

The following table lists common products to avoid using around sensors.

Cleaners and Lubricants	Silicones	Aerosols
Brake cleaners	Silicone cleaners and protectants	Bug repellents and sprays
Lubricants	Silicone based adhesives, sealants, and gels	Lubricants
Rust inhibitors	Hand/body and medicinal creams containing silicone	Rust inhibitors
Window and glass cleaners	Tissues containing silicone	Window cleaners
Dishsoaps	Mold releasing agents	
Citrus based cleaners	Polishes	
Alcohol based cleaners		
Hand sanitizers		
Anionic detergents		
Methanol (fuels and antifreezes)		

Inadvertent Sensor Poisoning?

- Volatile silicones:
  - Lubricants such as WD-40
  - Rust inhibitors
  - Plastic and rubber revival products such as ARMOR ALL
  - Waxes and polishes
  - Personal care products and makeup with ingredients such as cyclomethicone & polydimethylsiloxane
  - Heat transfer fluids
  - Silicone greases and oils
  - Caulking materials…
- Hydrogen sulphide and other sulphur containing compounds
- Phosphates and phosphorus containing substances
- Lead containing compounds (especially tetraethyl lead)
- Over Exposure to combustible gases

Only Use a Manufacturer Approved Cleaner

You can't use just any old cleaner on your dirty portable gas detector housing

✓ ACL Staticide is a proven cleaner for portable safety gas detectors
✓ Endorsed by the Honeywell BW Service Department

A Simple Test That Could Save Your Life!

Bump Test

- The safest course of action is to expose the sensors to a concentration of target gas that is capable of initiating a low alarm condition before each day's use!
- Even a manual Bump Test is very simple and takes only a few seconds to accomplish
- While in operating mode simply apply a concentration of gas that is capable of activating the alarms and meeting CSA criteria for the LEL sensor
- Automated BUMP test, calibration and record systems make the test even simpler and eliminate any human subjectivity

The only thing worse than a portable safety gas detector that you know doesn't work, is a portable safety gas detector that you don't know doesn't work.

ISEA Statement Excerpt

ISEA Statement on Validation of Operation For Direct Reading Portable Gas Monitors – 2010 March 10

2. Recommended Frequency

a. A bump test (function check) or calibration check of portable gas monitors should be conducted before each day's use in accordance with the manufacturer's instructions.
Any portable gas monitor which fails a bump test (function check) or calibration check must be adjusted by means of a full calibration procedure before further use, or removed from service.

b. A full calibration should be conducted at regular intervals in accordance with instructions specified by the instrument's manufacturer, internal company policy, or regulatory agency.

ISEA Statement Excerpt

Validation of an instrument's operability should be conducted if any of the following conditions or events occurs during use:

i. Chronic exposures to, and use in, extreme environmental conditions, such as
- high/low temperature and humidity, and high levels of airborne particulates.

ii. Exposure to high (over range) concentrations of the target gases and vapors.

iii. Chronic or acute exposure of catalytic hot-bead LEL sensors to poisons and inhibitors.
- These include volatile silicones, hydride gases, halogenated hydrocarbons, and
- sulfide gases.

iv. Chronic or acute exposure of electrochemical toxic gas sensors to solvent vapors
- and highly corrosive gases.

v. Harsh storage and operating conditions, such as when a portable gas monitor is
- dropped onto a hard surface or submerged in liquid. Normal handling/jostling of the
- monitors can create enough vibration or shock over time to affect electronic components
- and circuitry.

vi. Change in custody of the monitor.

vii. Change in work conditions that might have an adverse effect on sensors.

viii. Any other conditions that would potentially affect the performance of the monitor.

Record Keeping

- Automated BUMP testing, calibration and record keeping system
- Without good records you cannot defend your procedures
- If you don't have the records to prove it was being done right -- it wasn't!
- With the MicroDock II system, or INTELLIDOX, and Fleet Manager II software it is easy to produce compliance reports

Get in Touch

Call us

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- www.honeywellanalytics.com