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TR 1005:
G450 and G460 Multi-gas detectors

Advanced Confined Space User Training

February 27, 2013

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G460 advanced confined space gas detector user training

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G460 confined space training

- *This training presentation does not replace the G460 Owner's Manual*
- *Make sure the G460 instrument is used and maintained in conformance with all confined space program requirements*
- *Read and understand the G460 Owner's Manual before use!*

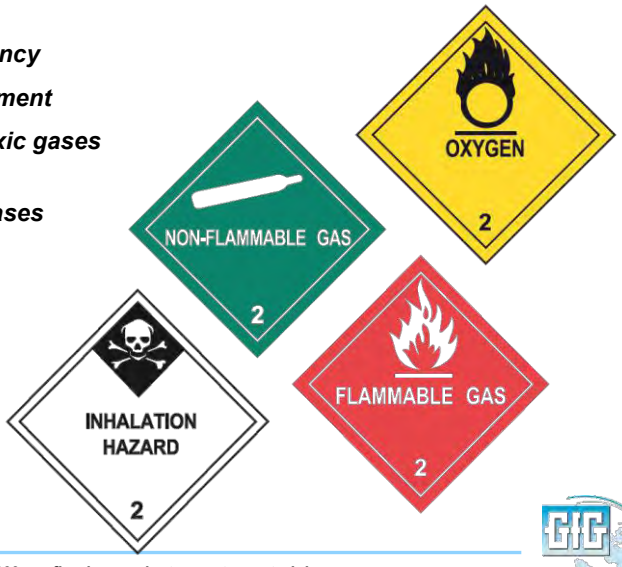
Confined space hazards

By the end of this lesson you should be able to:

- ***Name and understand the common atmospheric hazards***
- ***Understand TWA, STEL, IDLH, ppm and % by volume***
- ***Understand basic user procedures for G460 multi-gas atmospheric monitor***

Common atmospheric hazards

- ***Oxygen deficiency***
- ***Oxygen enrichment***
- ***Presence of toxic gases***
- ***Presence of combustible gases***



Atmospheric Testing
OSHA Regulations (29 CFR 1910.146)

263(1) Where an employee is about to enter into a confined space, an employer shall appoint a competent person to verify by tests that

(a) the concentration of airborne chemical agents or airborne dust in the confined space is not hazardous to the health or safety of the employee,

(b) the concentration of an airborne chemical agent or mixture of chemical agents or airborne dust in the confined space does not exceed 50% of its lower explosive limit,

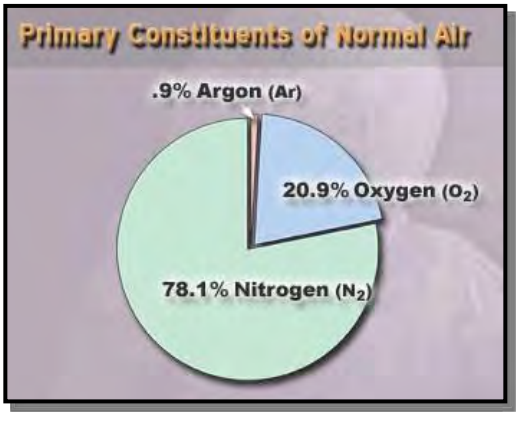
(c) the level of physical agents in the confined space is not hazardous to the health or safety of the employee,

(d) the percentage of oxygen in the atmosphere in the confined space is not less than 19.5% by volume and not more than 23% by volume,

(e) the concentration, level or percentage referred to in paragraphs (a) to (d) is able to be maintained during the period of proposed occupancy of the confined space by the employee,

Composition of fresh air

- ***78.1 % Nitrogen***
- ***20.9 % Oxygen***
- ***0.9 % Argon***
- ***0.1 % All other gases***
  - ***Water vapor***
  - ***CO_2***
  - ***Other trace gases***

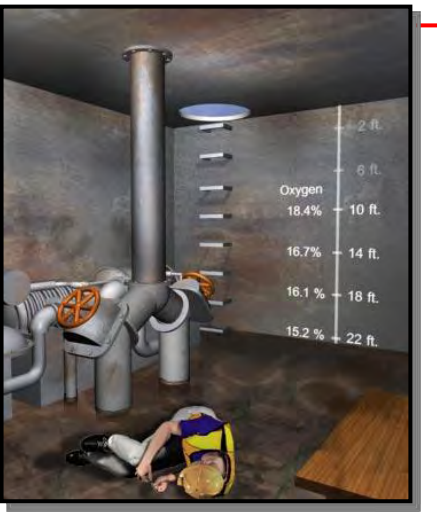


Oxygen Deficiency

- ***Any area that has an oxygen level of less then 19.5% by volume is considered to be oxygen deficient***

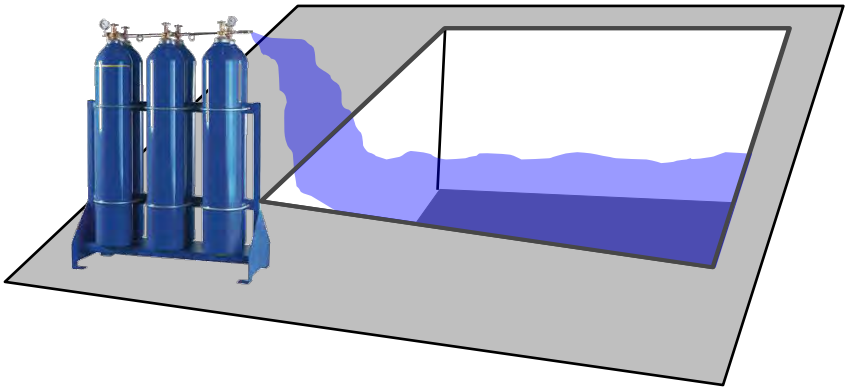
Causes of Oxygen Deficiency

- ***Combustion***
  - ***Welding and cutting torches***
  - ***Internal combustion engines***
- ***Decomposing of organic matter***
  - ***Rotting foods, plant life and fermentation***
- ***Oxidation of metals***
  - ***Rusting***
- ***Inerting***
- ***Displacement***
- ***Absorption***



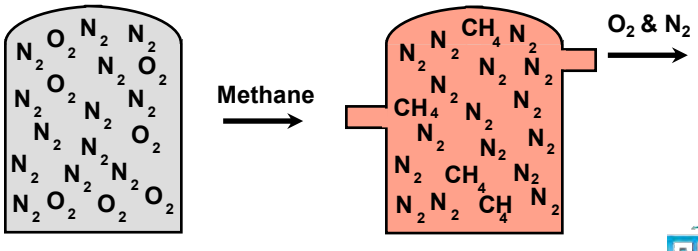
Oxygen displacement in an open topped confined space

Argon



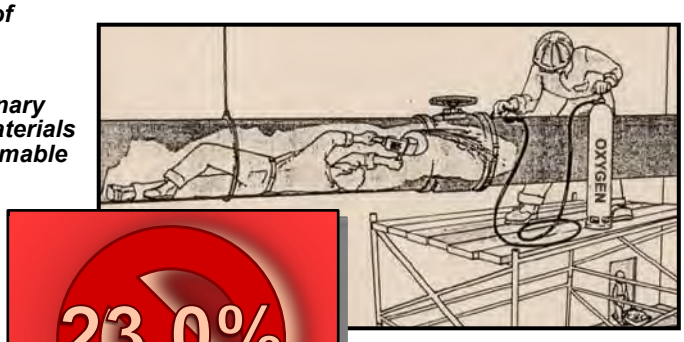
Deliberate displacement of oxygen (inertion) in a fully enclosed vessel

- *For every 5% total volume displaced, O2 concentration drops by about 1%*
- *If 5% of the fresh air in a closed vessel is displaced by methane, the O2 concentration would be about 19.9%*
- *The atmosphere would be fully explosive while the O2 concentration would still be above the normal alarm setting!*



Oxygen Enrichment

- *Proportionally increases rate of many chemical reactions*
- *Can cause ordinary combustible materials to become flammable or explosive*
- *Any area with an O_2 level of more than 23.0% is dangerously enriched*



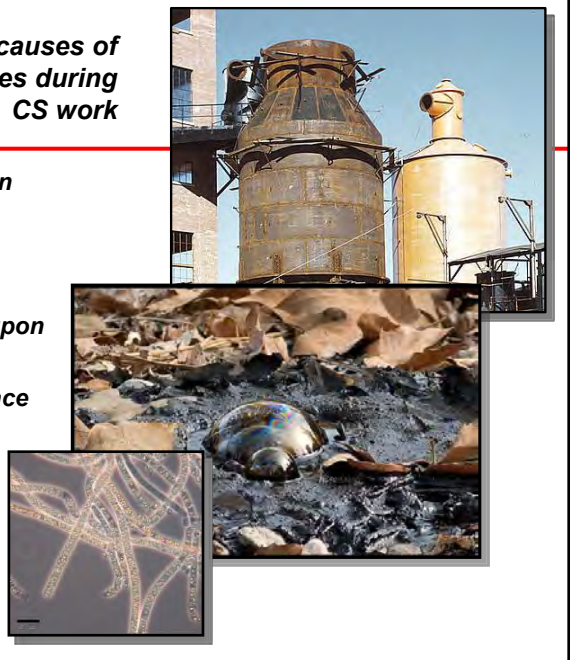
Effects of oxygen at various concentrations

Concentration	Effect
> 23%	Oxygen enrichment
20.90%	Normal air concentration
19.50%	Minimum "safe level"
16%	First sign of anoxia appears
16 – 12%	Breathing and pulse rate increase, muscular co-ordination is slightly impaired
14 – 10%	Consciousness continuous; emotional upsets, abnormal fatigue upon exertion, disturbed respiration
10 – 6%	Nausea and vomiting, inability to move freely and loss of consciousness may occur
< 6%	Convulsive movements and gasping occurs, respiration stops

Toxic Gases and Vapors

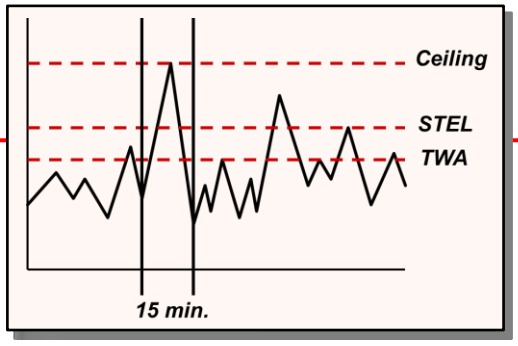
- *The two most common CS related toxic gases:*
  - *Hydrogen sulfide (H_2S)*
  - *Carbon monoxide (CO)*
- *<u>Many</u> other toxic gases related to specific activities and industries including:*
  - *Sulfur dioxide (SO_2)*
  - *Nitrogen dioxide (NO_2)*
  - *Chlorine (Cl_2)*
  - *Chlorine dioxide (ClO_2)*
  - *Ammonia (NH_3)*
  - *Cyanide (HCN)*
  - *Carbon dioxide (CO_2)*
  - *Volatile organic chemicals (VOCs)*

Common causes of toxic gases during CS work



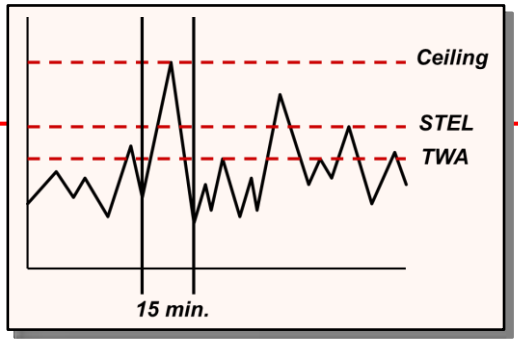
- *Contents that were stored in the space*
- *Compounds absorbed into walls of the space*
- *Contents being disturbed upon entry*
- *Work being done in the space*
- *Decomposing materials in the space*
- *Adjacent areas*

Toxic Exposure Limits



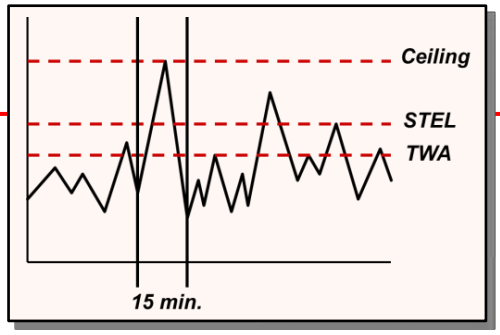
- *Toxic exposure limits are defined by means of:*
  - *8-hour TWA*
  - *15-minute STEL*
  - *Ceiling*
- *The exposure limit for a particular contaminant may include more than one part*

Toxic Exposure Limit Terms: TWA



- *TWA: The Time Weighted Average (TWA) is the exposure averaged over a full 8-hour shift*
- *When the monitoring session is less than eight hours, the TWA is projected for the full 8-hour shift*

Toxic Exposure Limit Terms: STEL

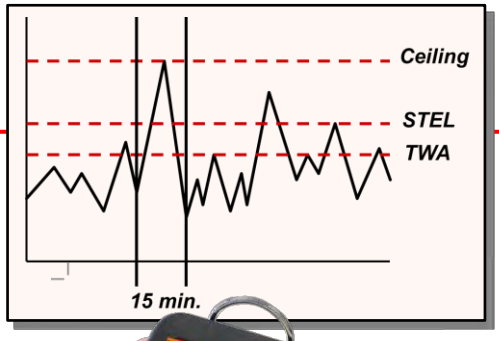


- *Some gases and vapors have an allowable maximum Short Term Exposure Limit (STEL) which is higher than the 8-hour TWA*
- *The STEL is the maximum average concentration to which an unprotected worker may be exposed during any 15-minute interval*

The average concentration may <u>never</u> exceed the STEL during any 15-minute interval

Any 15-minute interval where the average concentration is higher than the TWA (but less than the STEL) must be separated by at least 1-hour from the next, with a maximum of 4 times a shift

Ceiling Limit



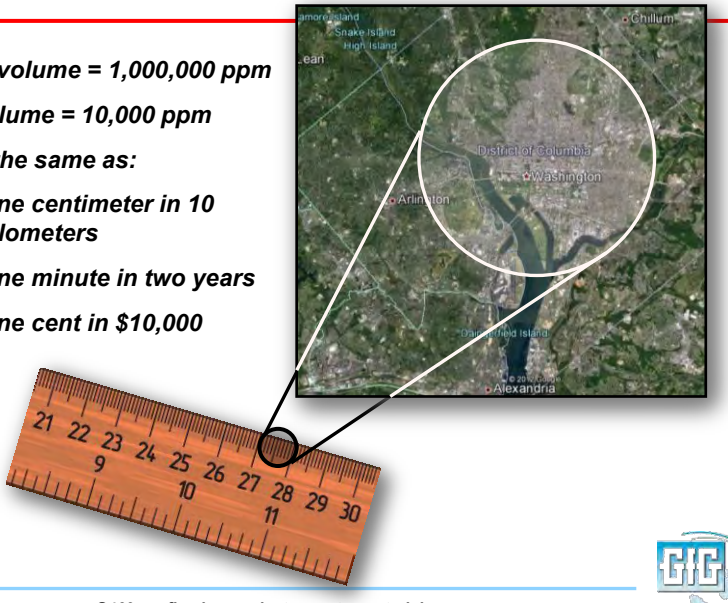
- *Ceiling is the maximum concentration to which an unprotected worker may be exposed*
- *Ceiling concentration should never be exceeded even for an instant*
- *The "Low Peak" and "High Peak" alarms in the G460 are activated whenever the concentration exceeds the alarm setting for even a moment*

Immediately Dangerous to Life and Health

- *IDLH is not part of permissible exposure limit*
  - *IDLH is maximum concentration from which it is possible for an unprotected worker to escape without suffering injury or irreversible health effects during a maximum 30-minute exposure*
  - *Primarily used to define the level and type of respiratory protection required*
  - *Unprotected workers may NEVER be deliberately exposed to IDLH or ANY concentrations which exceed the permissible exposure limit*

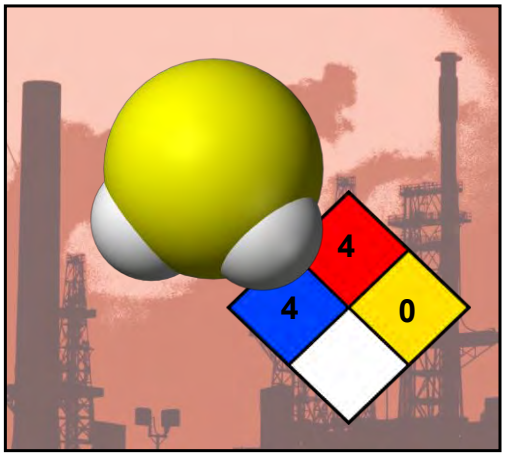
Meaning of parts-per-million (ppm)

- *100% by volume = 1,000,000 ppm*
- *1% by volume = 10,000 ppm*
- *1.0 ppm the same as:*
  - *One centimeter in 10 kilometers*
  - *One minute in two years*
  - *One cent in $10,000*



Characteristics of Hydrogen Sulfide

- *Colorless*
- *Smells like "rotten eggs" (at low concentrations)*
- *Heavier than air*
- *Corrosive*
- *Flammable (LEL is 4.3%)*
- *Soluble in water*
- *High concentrations kill sense of smell*
- *Extremely toxic!*



Toxic effects of H_2S

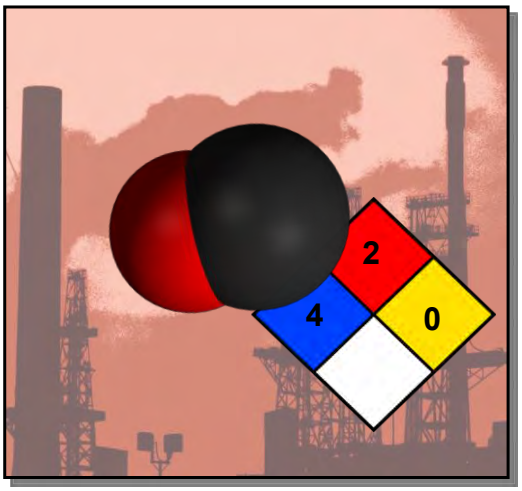
Toxic effects of H2S	
Concentration	*Symptoms*
0.13 ppm	*Minimal detectable odor*
4.6 ppm	*Easily detectable, moderate odor*
10.0 ppm	*Beginning eye irritation.*
27 ppm	*Strong unpleasant odor but not intolerable*
100 ppm	*Coughing, eye irritation, loss of smell after 2-5 min*
200 – 300 ppm	*Marked eye inflammation, rapid loss of smell, respiratory tract irritation, unconsciousness with prolonged exposure*
500 – 700 ppm	*Loss of consciousness and possible death in 30 to 60 min*
700 – 1,000 ppm	*Rapid unconsciousness, stopping or pausing of respiration and death*
1,000 – 2,000 ppm	*Immediate unconsciousness, death in a few minutes. Death may occur even if person is moved to fresh air*

H_2S Exposure Limits

Toxic exposure limits for H2S			
	8-hour TWA	*15-minute STEL*	*Ceiling*
USA NIOSH	*10*	*15*	*NA*
USA OSHA Confined Space (1910.146)	*10*	*NA*	*NA*
ACGIH TLV (Old)	*10*	*15*	*NA*
ACGIH TLV (2010)	*1*	*5*	*NA*

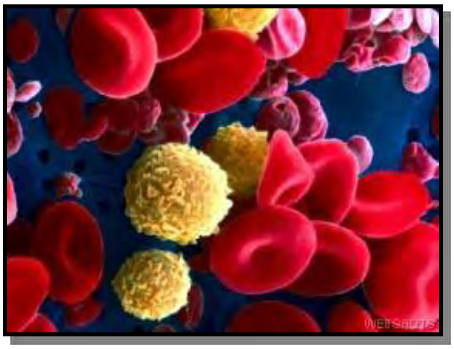
Characteristics of Carbon Monoxide

- *Colorless*
- *Odorless*
- *Slightly lighter than air*
- *By-product of combustion*
- *Flammable (LEL is 12.5%)*
- *Toxic!*



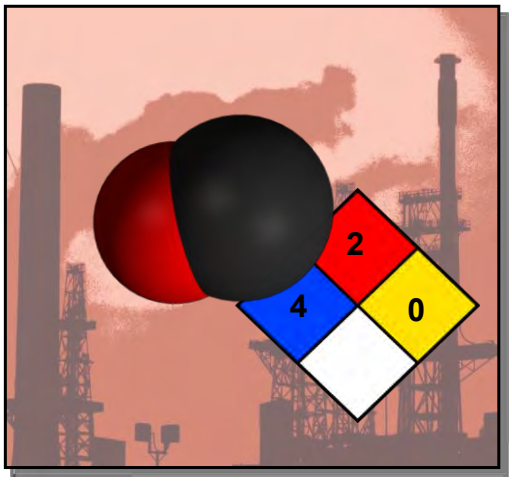
Carbon Monoxide

- *Bonds to hemoglobin in red blood cells*
- *Contaminated cells can't transport O_2*
- *Chronic exposure at even low levels harmful*



Toxic Effects CO

- *Concentration of only 1,600 ppm fatal within hours*
- *Even lower level exposures can result in death if there are underlying medical conditions, or when there are additional factors (such as heat stress)*

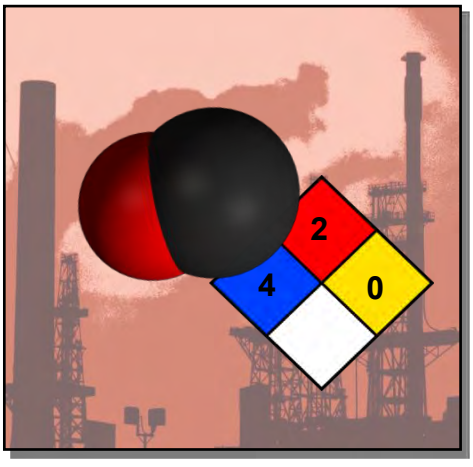


Toxic effects of CO

Toxic effects of carbon monoxide	
25 ppm	TLV exposure limit for 8 hours (TWA)
200 ppm	Possible mild frontal headaches in 2-3 hours
400 ppm	Frontal headaches and nausea after 1-2 hours.
800 ppm	Headache, dizziness and nausea in 45 min. Collapse and possibly death in 2 hours
1,600 ppm	Headache and dizziness in 20 min. Unconsciousness and danger of death in 2 hours
3,200 ppm	Headache and dizziness in 5-10 min. Unconsciousness and danger of death 30 min.
6,400 ppm	Headache and dizziness in 1-2 min. Unconsciousness and danger of death 10-15 min
12,800 ppm	Unconsciousness immediately, danger of death in 1-3 min.

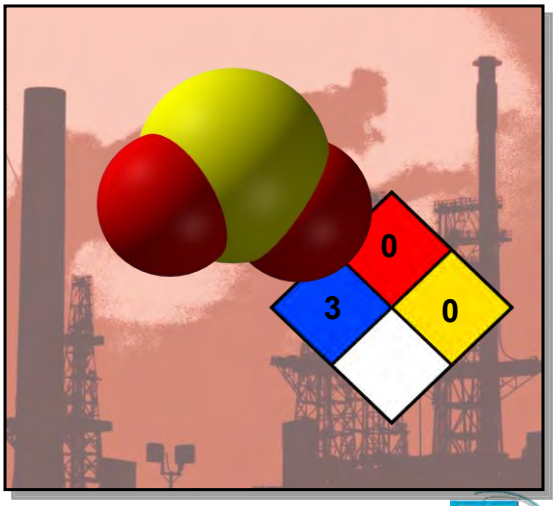
Exposure Limits for Carbon Monoxide

- OSHA PEL:
  - 50 ppm 8-hr. TWA
- NIOSH REL:
  - 35 ppm 8-hr. TWA
  - 200 ppm Ceiling
- TLV:
  - 25 ppm 8-Hr. TWA



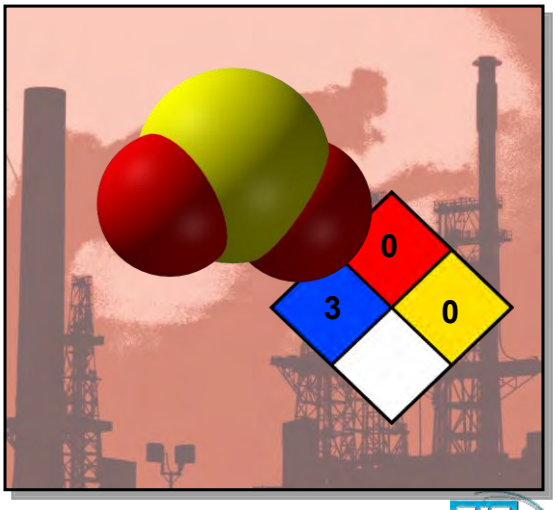
Characteristics of SO_2

- *Colorless gas*
- *Irritating, pungent odor*
- *Heavier than air*
- *Reacts with H_2O to form sulfurous acid*
- *Respiratory irritant*
- *Toxic!*



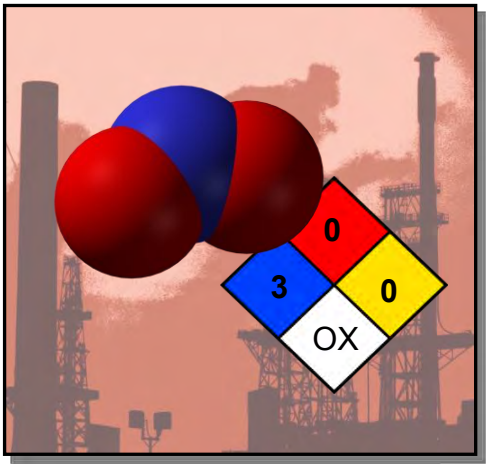
Exposure limits for SO_2

- *OSHA PEL:*
  - *TWA = 5.0 ppm*
- *NIOSH REL:*
  - *TWA = 2.0 ppm*
  - *STEL = 5.0 ppm*
- *Old TLV :*
  - *TWA = 2 ppm*
  - *STEL = 5 ppm*
- *New (2009) TLV:*
  - *STEL = 0.25 ppm*



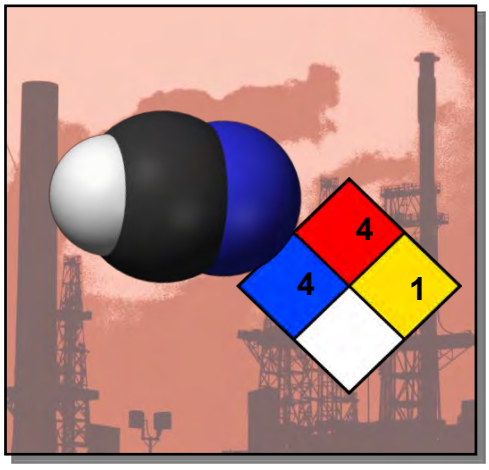
Exposure limits for NO_2

- *Old TLV:*
  - *8 hr. TWA = 3 ppm*
  - *5 min. STEL = 5 ppm*
- *New 2012 TLV*
  - *8 hr. TWA = 0.2 ppm*
- *US OSHA PEL:*
  - *Ceiling = 5 ppm*
- *US NIOSH REL:*
  - *15 min. STEL = 1 ppm*



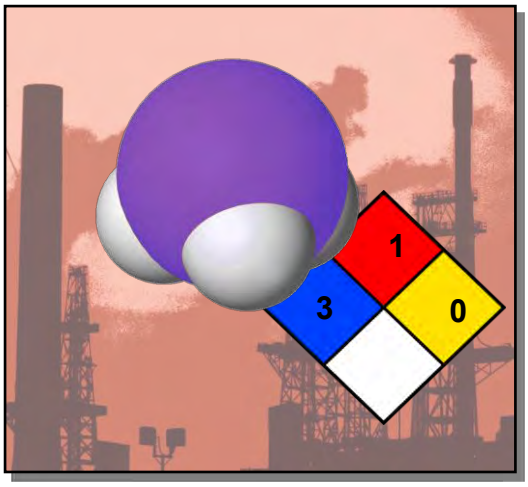
Exposure limits for HCN

- *US OSHA PEL:*
  - *TWA = 10 ppm*
- *US NIOSH REL:*
  - *15 min. STEL = 4.7 ppm*
- *TLV:*
  - *Ceiling = 4.7 ppm*



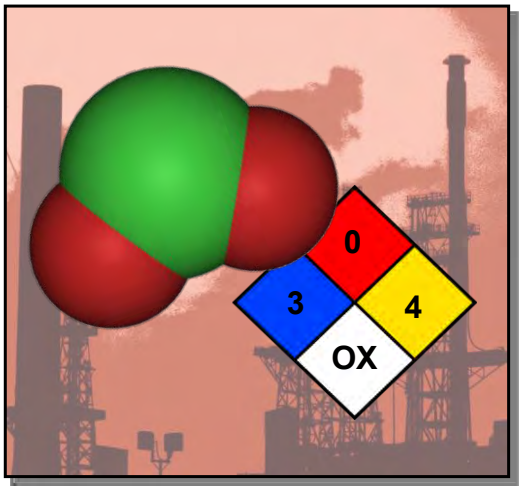
Exposure limits for NH_3

- *US OSHA PEL:*
  - *TWA = 50 ppm*
- *US NIOSH REL:*
  - *8 hr. TWA = 25 ppm*
  - *15 min. STEL = 35 ppm*
- *TLV:*
  - *8 hr. TWA = 25 ppm*
  - *15 min. STEL = 35 ppm*



Characteristics of Chlorine Dioxide (ClO_2)

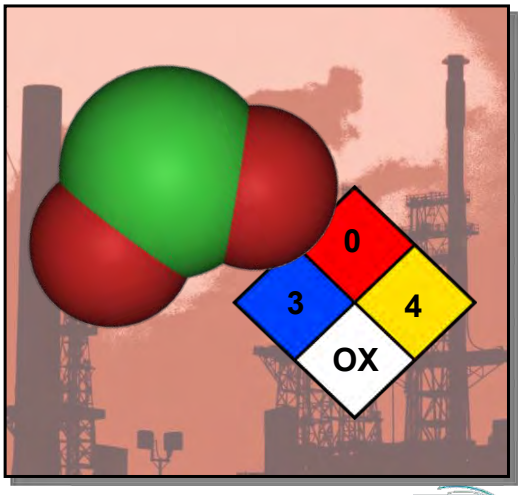
- *Yellow to reddish gas*
- *Strong oxidizer*
- *Odor similar to chlorine*
- *Heavier than air*
- *Used in water treatment and as bleaching agent (pulp and paper)*
- *Extremely toxic!*



Exposure limits for Chlorine Dioxide (ClO_2)

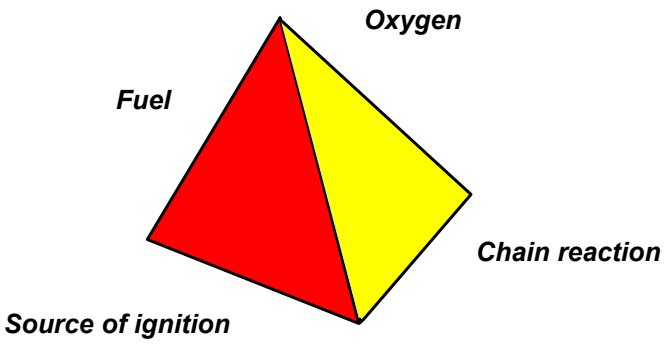
- *OSHA PEL:*
  - *0.1 ppm (8-hr. TWA)*
- *NIOSH REL:*
  - *0.1 ppm (8-hr. TWA)*
  - *0.3 ppm STEL*
- *TLV:*
  - *0.1 ppm (8-hr. TWA)*
  - *0.3 ppm STEL*

Remember: it only takes 0.000001% by volume to exceed the exposure limit !!!



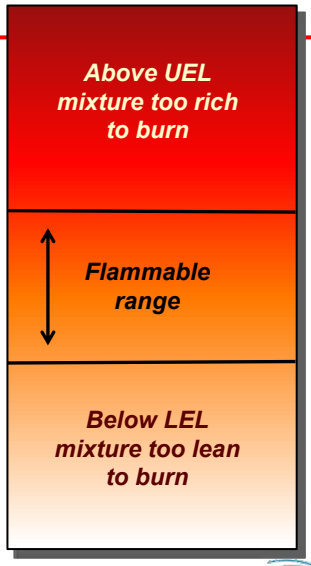
Explosive or Flammable Atmospheres

Fire Tetrahedron



Explosive limits

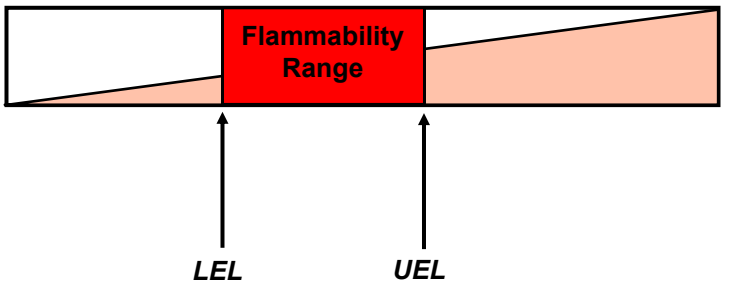
- Lower Explosive Limit (LEL):
  - Minimum concentration of a combustible gas or vapor in air which will ignite if a source of ignition is present
- Upper Explosive Limit (UEL):
  - Most but not all combustible gases have an upper explosive limit
  - Maximum concentration in air which will support combustion
  - Concentrations which are above the UEL are too "rich" to burn



Flammability Range

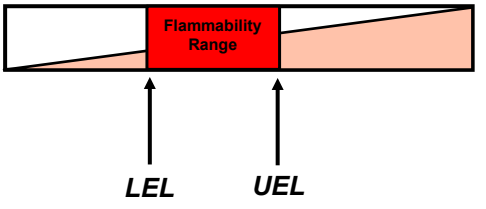
- *The range between the LEL and the UEL of a combustible gas or vapor*
- *Concentrations within the flammable range will burn or explode if a source of ignition is present*

Gas Concentration



Different gases have different flammability ranges

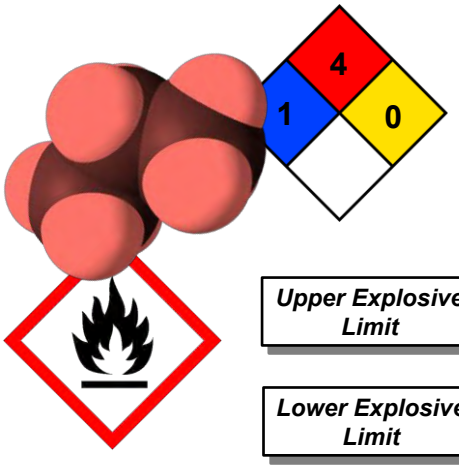
Gas Concentration

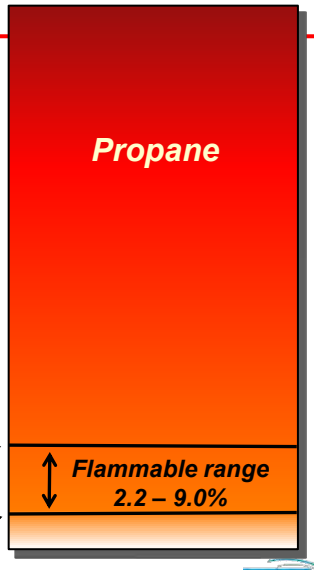


Fuel Gas	LEL (%VOL)	UEL (%VOL)
Acetylene	2.2	85
Ammonia	15	28
Benzene	1.3	7.1
Butane	1.8	8.4
Carbon Monoxide	12	75
Ethylene	2.7	36
Ethylene oxide	3.0	100
Ethyl Alcohol	3.3	19
Fuel Oil #1 (Diesel)	0.7	5
Hydrogen	4	75
Isobutylene	1.8	9
Isopropyl Alcohol	2	12
Gasoline	1.4	7.6
Kerosine	0.7	5
Methane	5	15
MEK	1.8	10
Hexane	1.1	7.5
Pentane	1.5	7.8
Propane	2.1	10.1
Toluene	1.2	7.1
p-Xylene	1.1	7.0

Explosive Limits

- Propane (C_3H_8)



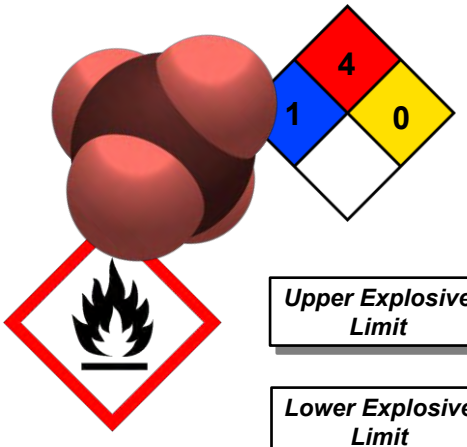


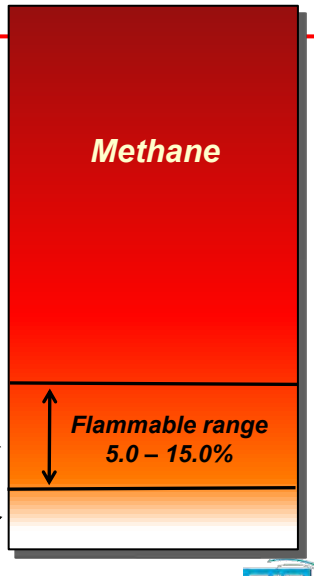
Upper Explosive Limit

Lower Explosive Limit

Explosive Limits

- Methane (CH_4)



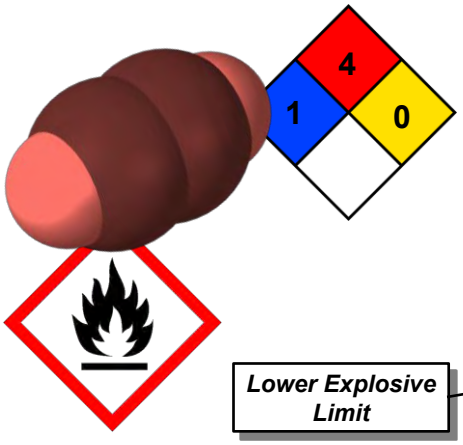


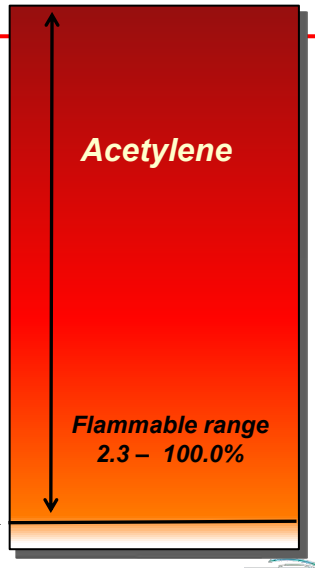
Upper Explosive Limit

Lower Explosive Limit

Explosive Limits

- *Acetylene (C_2H_4) has no Upper Explosion Limit!*

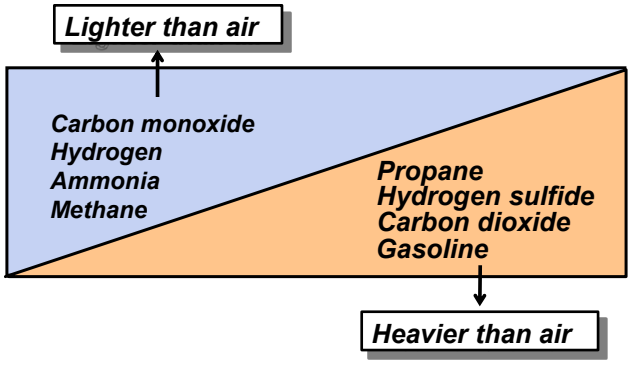




Lower Explosive Limit

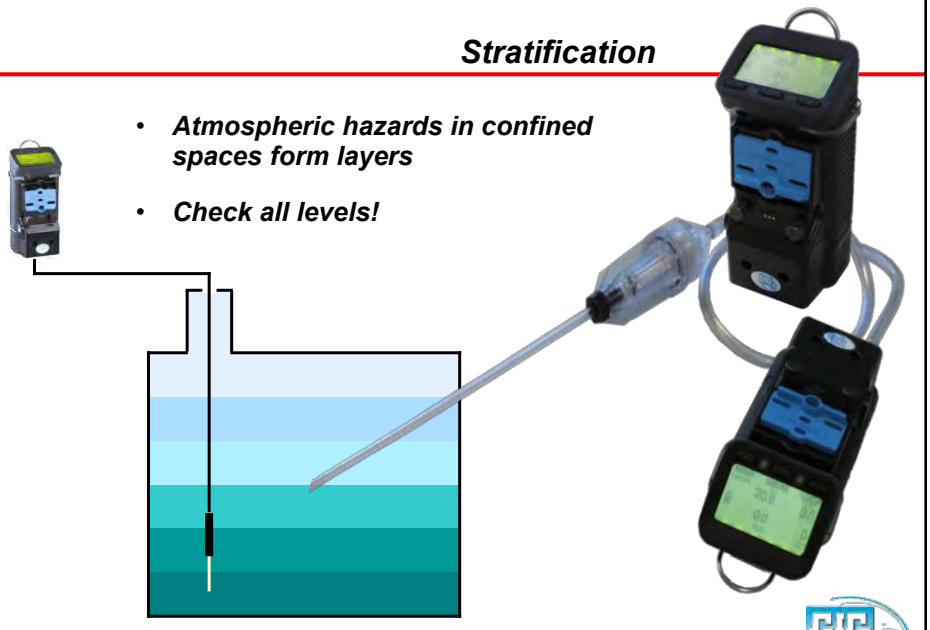
Vapor density

- *Measure of a vapor's weight compared to air*
- *Gases lighter than air tend to rise; gases heavier than air tend to sink*



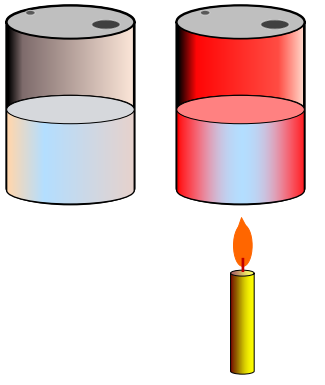
Stratification

- *Atmospheric hazards in confined spaces form layers*
- *Check all levels!*



Vaporization is a function of temperature

- *Vapors are the gaseous state of substances that are either liquids or solids at room temperatures*
  - *Gasoline evaporates*
  - *Dry ice (solid carbon dioxide) sublimates*
- *Increasing the temperature of the combustible liquid increases the amount of vapor produced*



Flashpoint Temperature

- ***Temperature at which a combustible liquid gives off enough vapor to form an ignitable mixture***

	Degrees F	Degrees C
Gasoline (aviation grade)	*- 50 °F (approx.)*	*- 45 °C (approx.)*
Acetone	*0 °F*	*- 18 °C*
Methyl ethyl ketone	*24 °F*	*- 4 °C*
Ethanol (96 %)	*62 °F*	*17 °C*
Diesel oil	*100 - 190 °F*	*38 - 88 °C*

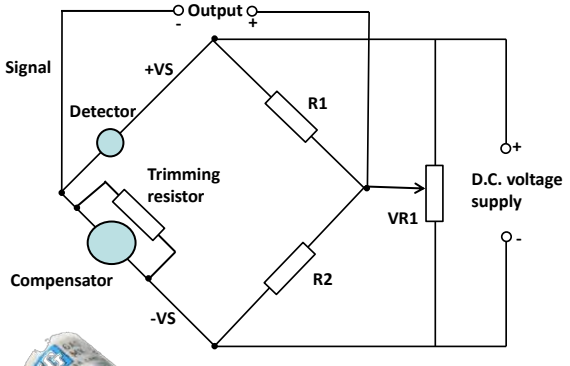
How combustible (percent LEL) gas detecting instruments detect gas

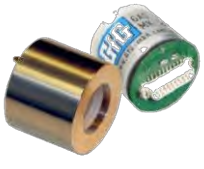
Catalytic "Hot Bead" Combustible Sensor

- *Detects combustible gas by catalytic oxidation*
- *When exposed to gas oxidation reaction causes bead to heat*
- *Requires oxygen to detect gas!*

Catalytic "Hot Bead" Combustible Sensor

- *Detects combustible gas by catalytic oxidation*
- *When exposed to gas oxidation reaction causes the active (detector) bead to heat*
- *Requires oxygen to detect gas!*





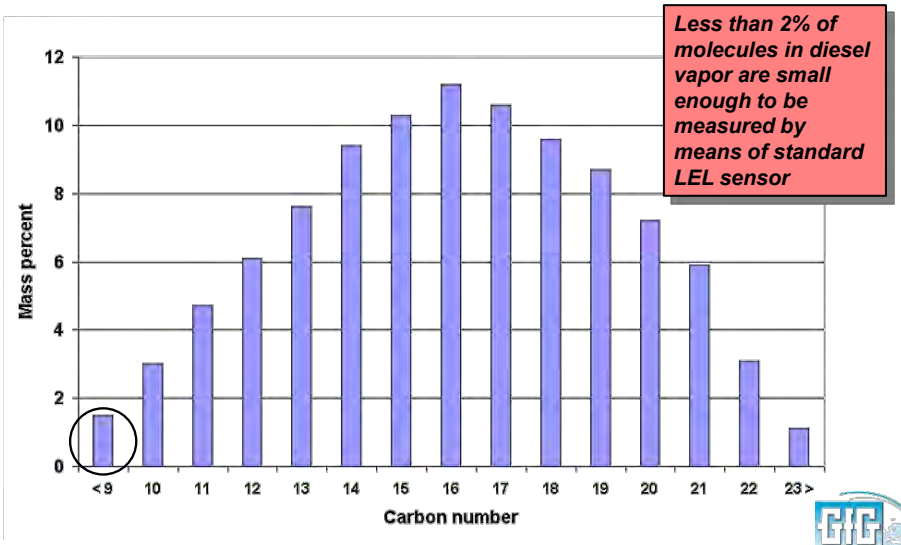
Traditional LEL sensors are "Flame proof" devices

- *Flame proof sensors depend on physical barriers such as stainless steel housings and flame arrestors to limit the amount of energy that can ever be released by the sensor*
- *The flame arrestor can slow, reduce, or even prevent larger molecules from entering the sensor*
- *The larger the molecule, the slower it diffuses through the flame arrestor into the sensor*
- *The response of the sensor is so slow to molecules larger than nonane (C9) in size that they are effectively undetectable*

Stainless steel housing

Flame arrestor (sinter)

Typical carbon number distribution in No. 2 Diesel Fuel (liquid)

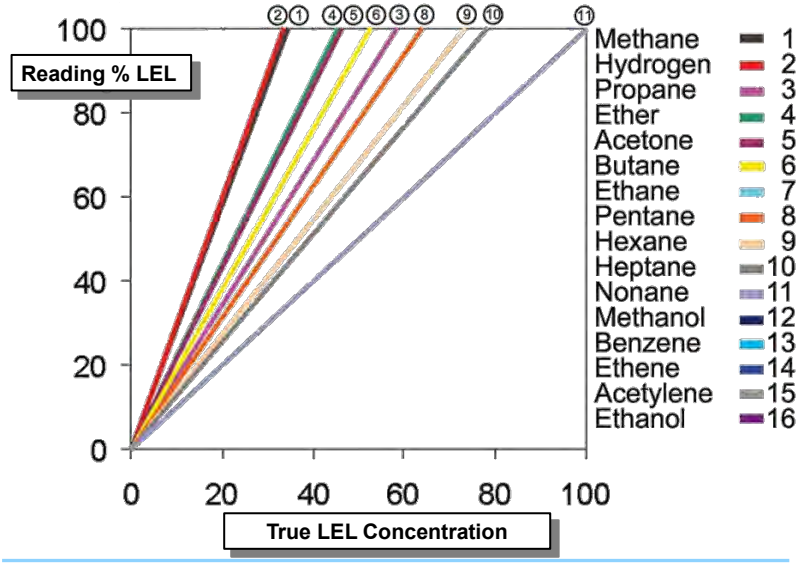


Less than 2% of molecules in diesel vapor are small enough to be measured by means of standard LEL sensor

Typical catalytic LEL sensor relative responses

Relative responses of 4P-75 catalytic LEL sensor			
Combustible gas / vapor	Relative response when sensor calibrated on pentane	Relative response when sensor calibrated on propane	Relative response when sensor calibrated on methane
Hydrogen	2.2	1.7	1.1
Methane	2.0	1.5	1.0
Propane	1.3	1.0	0.7
n-Butane	1.2	0.9	0.6
n-Pentane	1.0	0.8	0.5
n-Hexane	0.9	0.7	0.5
n-Octane	0.8	0.6	0.4
Methanol	2.3	1.8	1.2
Ethanol	1.6	1.2	0.8
Isopropanol	1.4	1.1	0.7
Acetone	1.4	1.1	0.7
Ammonia	2.6	2.0	1.3
Toluene	0.7	0.5	0.4
Gasoline (unleaded)	1.2	0.9	0.6

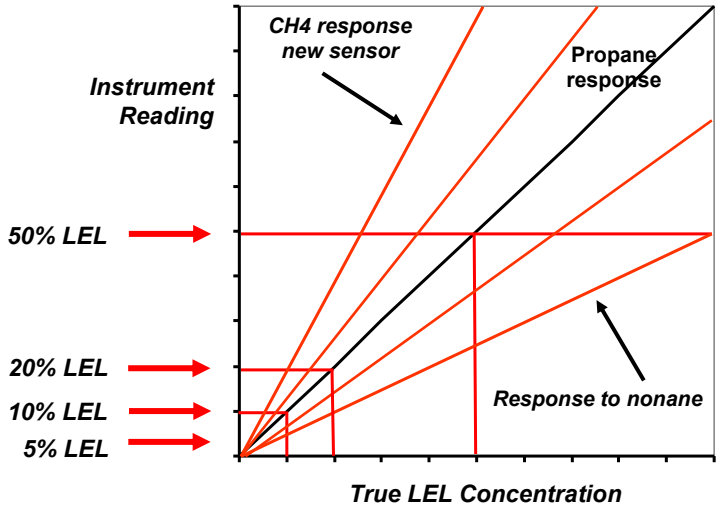
Catalytic pellistor combustible gas response curves



Catalytic combustible LEL sensor correction factors

Correction factors for 4P-75 catalytic LEL sensor			
Combustible gas / vapor	Relative response when sensor calibrated on pentane	Relative response when sensor calibrated on propane	Relative response when sensor calibrated on methane
Hydrogen	0.45	0.59	0.91
Methane	0.50	0.67	1.00
Propane	0.77	1.00	1.54
n-Butane	0.83	1.11	1.67
n-Pentane	1.00	1.33	2.00
n-Hexane	1.11	1.43	2.22
n-Octane	1.25	1.67	2.50
Methanol	0.43	0.57	0.87
Ethanol	0.63	0.83	1.25
Isopropanol	0.71	0.95	1.43
Acetone	0.71	0.95	1.43
Ammonia	0.38	0.50	0.77
Toluene	1.43	2.00	2.86
Gasoline (unleaded)	0.83	1.11	1.67

Using a lower alarm setting minimizes effect of relative response on readings



Limitations of catalytic pellistor LEL sensors

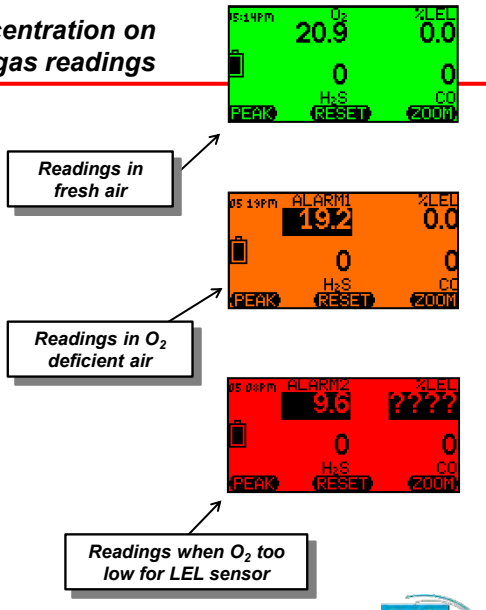
- *Flame arrestor limits molecules larger than nine carbons (nonane) from entering sensor*
- *Even when molecules are able to diffuse into sensor: the larger the molecule the lower the relative response*
- *Easily poisoned*
- *Exposure to high concentration combustible gas damaging to sensor*

Combustible sensor limitations

Contaminant	LEL (Vol %)	Flashpoint Temp (°F)	OSHA PEL	NIOSH REL	TLV	5% LEL in PPM
Acetone	2.5%	-4°F (-20 °C)	1,000 PPM TWA	250 PPM TWA	500 PPM TWA; 750 PPM STEL	1250 PPM
Diesel (No.2) vapor	0.6%	125°F (51.7°C)	None Listed	None Listed	15 PPM	300 PPM
Ethanol	3.3%	55°F (12.8 °C)	1,000 PPM TWA	1000 PPM TWA	1000 PPM TWA	1,650 PPM
Gasoline	1.3%	-50°F (-45.6°C)	None Listed	None Listed	300 PPM TWA; 500 PPM STEL	650 PPM
n-Hexane	1.1%	-7°F (-21.7 °C)	500 PPM TWA	50 PPM TWA	50 PPM TWA	550 PPM
Isopropyl alcohol	2.0%	53°F (11.7°C)	400 PPM TWA	400 PPM TWA; 500 PPM STEL	200 PPM TWA; 400 PPM STEL	1000 PPM
Kerosene/ Jet Fuels	0.7%	100 – 162°F (37.8 – 72.3°C)	None Listed	100 mg/M3 TWA (approx. 14.4 PPM)	200 mg/M3 TWA (approx. 29 PPM)	350 PPM
MEK	1.4%	16°F (-8.9°C)	200 PPM TWA	200 PPM TWA; 300 PPM STEL	200 PPM TWA; 300 PPM STEL	700 PPM
Turpentine	0.8	95°F (35°C)	100 PPM TWA	100 PPM TWA	20 PPM TWA	400 PPM
Xylenes (o, m & p isomers)	0.9 – 1.1%	81 – 90°F (27.3 – 32.3 °C)	100 PPM TWA	100 PPM TWA; 150 PPM STEL	100 PPM TWA; 150 STEL	450 – 550 PPM

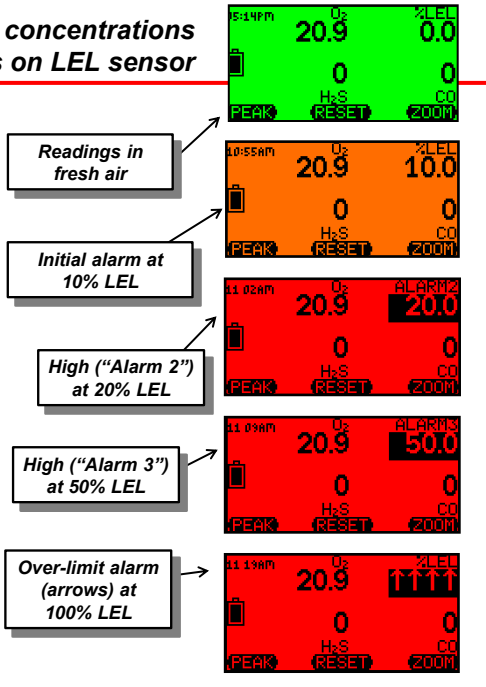
Effects of O_2 concentration on combustible gas readings

- *Look at O_2 readings first!*
- *LEL readings may be affected if levels of O_2 are higher or lower than fresh air*
- *Catalytic LEL sensors require a minimum level of 10% oxygen to read LEL*
- *If the O_2 concentration is too low the LEL reading should be replaced with question marks*



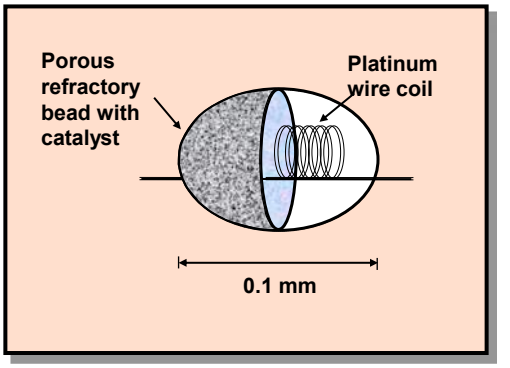
Effects of high concentrations of gas on LEL sensor

- *When doing atmospheric testing we are only concerned with the LEL. Why is that?*
  - *Work is not permitted in areas where the concentration of gas exceeds safety limits!*
  - *If the explosive gas concentration is too high there may not be enough oxygen for the LEL sensor to detect properly*
  - *Concentrations above 100% LEL can damage the LEL sensor*



Combustible Gas Sensor

- *The catalyst in the LEL sensor bead can be harmed if it is exposed to certain substances*
- *LEL sensor poisons permanently reduce or destroy the sensor's response to gas*
- *The most common LEL sensor poisons are silicon containing vapors (like the silicones used in Armour All)*
- *Sensors which may have been exposed to a poison must be tested before further use*



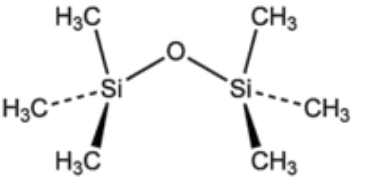
Combustible sensor poisons

- *Combustible sensor poisons:*
  - *Silicones (by far the most virulent poison)*
  - *Hydrogen sulfide*

    Note: The LEL sensor includes an internal filter that is more than sufficient to remove the H_2S in calibration gas. It takes very high levels of H_2S to overcome the filter and harm the LEL sensor
  - *Other sulfur containing compounds*
  - *Phosphates and phosphorus containing substances*
  - *Lead containing compounds (especially tetraethyl lead)*
  - *High concentrations of flammable gas!*
- *Combustible sensor inhibitors:*
  - *Halogenated hydrocarbons (Freons®, trichloroethylene, methylene chloride, etc.)*

"Silicone resistant" vs. "standard" pellistor type LEL sensors

- ***"Silicone resistant" combustible sensors have an <u>external</u> silicone filter capable of removing most silicone vapor before it can diffuse into the sensor***
  - ***Silicone vapor is the most virulent of all combustible sensor poisons***
  - ***Filter also slows or slightly reduces response to heavier hydrocarbons such as hexane, benzene, toluene, xylene, cumene, etc.***
  - ***The heavier the compound, the greater the effect on response (should not be used on C8 – C9 hydrocarbons)***



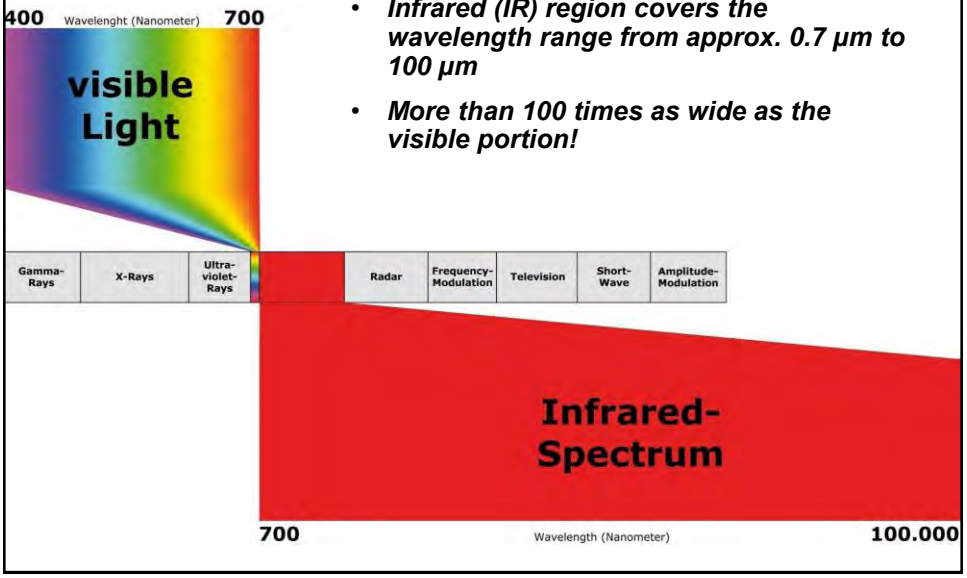
Combustible sensor advice

- ***Whatever the brand, allow enough time for full stabilization prior to performing fresh air zero***
  - ***Do not perform auto-zero as part of automatic start-up sequence***
  - ***Wait at least 5 minutes after initially turning instrument on before performing a fresh air zero***
- ***Perform functional test before each day's use!***
- ***Use methane based test gas mixture OR if you use a different gas (e.g. propane or pentane) challenge the sensor with methane periodically to verify whether the sensor has disproportionately lost sensitivity to methane***

Non-dispersive infrared (NDIR) sensors

- *Many gases absorb infrared light at a unique wavelength (color)*
- *In NDIR sensors the amount of IR light absorbed is proportional to the amount of target gas present*
- *The longer the optical path through the sensor the better the resolution*

Electromagnetic radiation spectrum



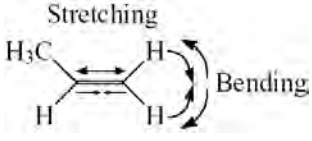
- *Infrared (IR) region covers the wavelength range from approx. 0.7 µm to 100 µm*
- *More than 100 times as wide as the visible portion!*

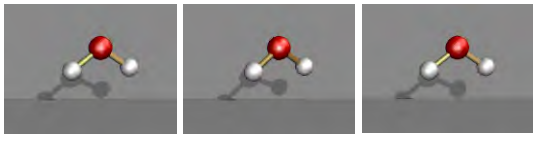
Infrared Detectors

- *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*
- *Thus, specific molecules absorb infrared radiation at precise frequencies*

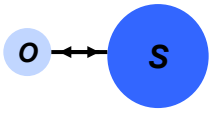
Energy Absorbed by "Bond Stretching" and "Bending" Vibration

- *Must have a COVALENT CHEMICAL BOND*





Symmetric Stretch *Asymmetric Stretch* *Bend*



Linear molecules: SO

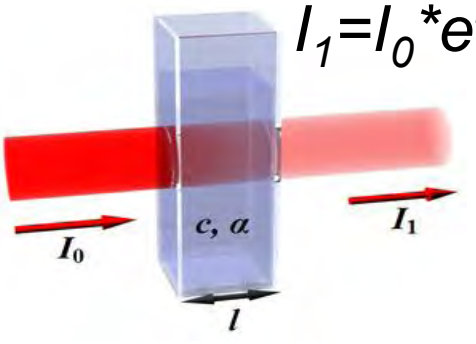
Nonlinear Molecules

Infrared Detectors

- *When infra-red 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*

Beer-Lambert Law

$$I_1 = I_0 * e^{-\alpha L c}$$



Size (length) matters...

- I_0 *is the intensity of the incident light*
- I_1 *is the intensity after passing through the material*
- *L is the distance that the light travels through the material (the path length)*
- *c is the concentration of absorbing species in the material*
- *α is the absorption coefficient or the molar absorptivity of the absorber*

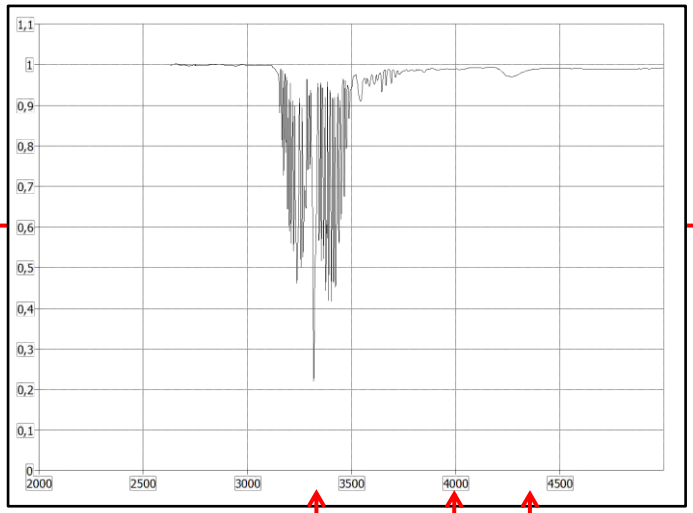
Requirements for IR Absorption

- *Saturated hydrocarbon molecules like methane, propane, butane, pentane, hexane, octane, etc. and alcohols are highly detectable by IR*
- *Mixtures rich in saturated hydrocarbons such as gasoline, jet fuel, diesel and kerosene also readily detectable by IR*
- *CO_2 absorbs IR very well*
- *Molecules with double (C=C) or triple (C≡C) bonds do not absorb IR as readily as saturated hydrocarbon molecules*
- *Diatomic molecules such as ones on the following list DO NOT absorb IR at all:*
  - *N_2*
  - *O_2*
  - *F_2*
  - *Cl_2*
  - *Hg_2*
  - *Ar*

IR sensors cannot be used to measure hydrogen (H_2) or acetylene!

Wavelengths used for NDIR measurement

- *LEL: 3.3 µm*
- *CO_2: 4.3µm*
- *Reference: 4.0µm*



Photoionization Detectors

- *Used for measuring solvent, fuel and VOC vapors in the workplace environment*

Volatile organic compounds (VOCs)

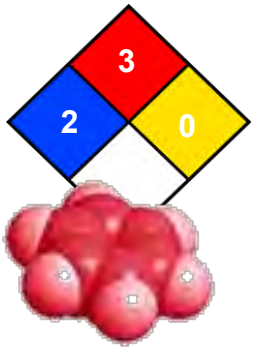
- *VOCs are organic compounds characterized by tendency to evaporate easily at room temperature*
- *Familiar VOCs include:*
  - *Solvent*
  - *Paint thinner*
  - *Nail polish remover*
  - *Gasoline*
  - *Diesel*
  - *Heating oil*
  - *Kerosene*

Volatile organic compounds (VOCs)

- *Solvent, fuel and other VOC vapors common in many workplace environments*
- *Most have surprisingly low occupational exposure limits*
- *Long before you reach a concentration sufficient to register on a combustible gas indicator, you will have easily exceeded the toxic exposure limits for most VOC contaminants*
- *PID equipped instruments generally the best choice for measurement of VOCs at exposure limit concentrations*

VOC Toxicity

- *VOCs present multiple potential threats in the workplace environment*
- *Heavier than air, flammable and toxic*
- *Increased awareness of toxicity is leading to lowered exposure limits*
- *This leads in turn to increased need for direct measurement of VOCs at exposure limit concentrations*



PID - Operating Principle

- *PIDs use ultraviolet light as source of energy to remove an electron from neutrally charged target molecules creating electrically charged fragments (ions)*
- *This produces a flow of electrical current proportional to the concentration of contaminant*
- *The amount of energy needed to remove an electron from a particular molecule is the ionization potential (or IP)*
- *The energy must be greater than the IP in order for an ionization detector to be able to detect a particular substance*

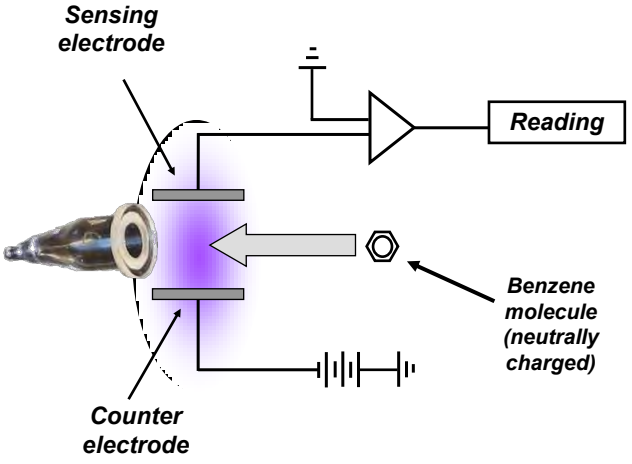
LEL vs. PID Sensors

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

Operation of PID lamp, sensing and counter electrodes

Detection sequence:

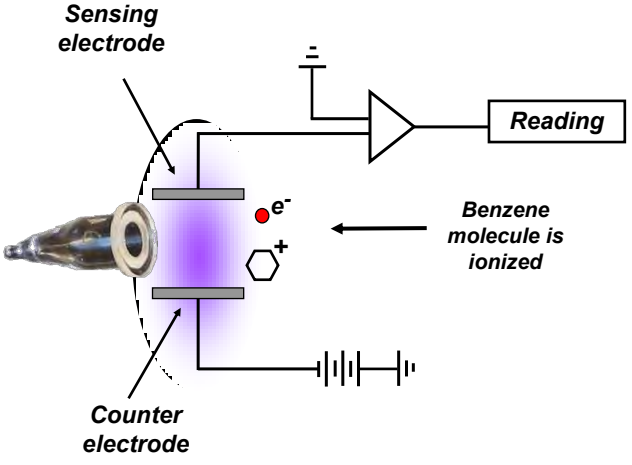
1. Neutrally charged molecule diffuses into glow zone



Operation of PID lamp, sensing and counter electrodes

Detection sequence:

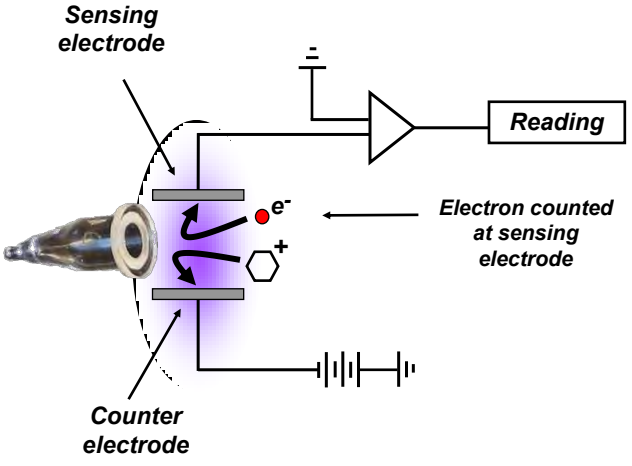
2. Molecule is ionized



Operation of PID lamp, sensing and counter electrodes

Detection sequence:

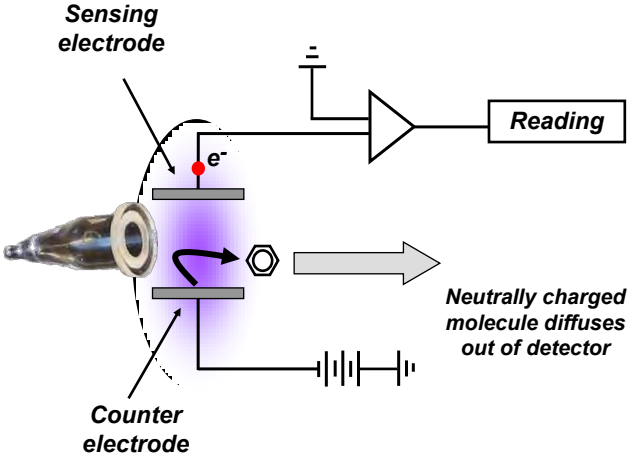
3. Free electron is electrostatically accelerated to positively charged sensing electrode where it is counted



Operation of PID lamp, sensing and counter electrodes

Detection sequence:

4. Positively charged fragment (ion) is electrostatically accelerated to counter electrode, where it picks up a replacement electron and regains neutral charge



Ionization Energy

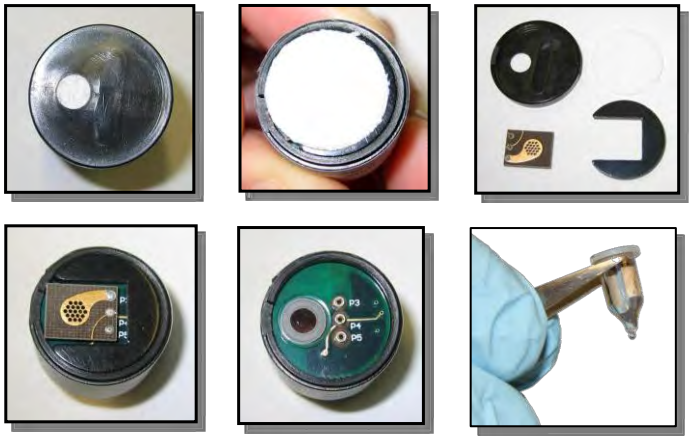
- ***IE determines if the PID can detect the gas***
- ***If the IE of the gas is less than the eV output of the lamp the PID can detectthe gas***
- ***Ionization Energy (IE) measures the bond strength of a gas and does not correlate with the Correction Factor***
- ***Ionization Potentials are found in the NIOSH Pocket Guide and many chemical texts***

Ionization Energy Values

Ionization energy values	
Gas / vapor	Ionization energy (eV)
Carbon monoxide	14.01
Carbon dioxide	13.77
Methane	12.98
Water	12.59
Oxygen	12.08
Chlorine	11.48
Hydrogen sulfide	10.46
n-Hexane	10.18
Ammonia	10.16
hexane (mixed isomers)	10.13
acetone	9.69
benzene	9.25
butadiene	9.07
toluene	8.82

PID Components

- *Detector assembly*
- *Electrodes: sensing, counter and (in some designs) fence*
- *Lamp: most commonly 10.6EV, 11.7eV or 9.8 eV*



PID lamp characteristics

- *Window material and the filler gas determine output characteristics as well as operational life of lamp*

PID lamp characteristics						
Nominal lamp photon energies	Primary gas in lamp	Major emission lines		Relative intensity	Window crystal	Crystal transmittance λ range (nm)
		eV	λ (nm)			
11.7 eV	Argon	11.83	104.8	1000	Lithium fluoride (LiF)	105 - 5000
		11.62	106.7	500		
10.6 eV	Krypton	10.64	116.5	200	Magnesium fluoride (MgF_2)	115 - 7000
		10.03	123.6	650		
9.8 eV	Krypton	10.03	123.6	650	Calcium fluoride (CaF_2)	125 - 8000

Critical PID Performance Issues: Effects of Humidity and Contamination

- *Condensation and contamination on lamp window and sensor surfaces can create surface conduction paths between sensing and counter electrodes*
- *Buildup of contamination provides nucleation points for condensation, leading to surface currents*
- *If present, surface currents cause false readings and / or add significant noise that masks intended measurement (sometimes called "moisture leakage")*
- *PID designs <u>MAY</u> require periodic cleaning of the lamp and detector to minimize the effects of contaminants and humidity condensation on PID readings*

PID as "Broad-Range" Sensor

- *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 single total reading for all detectable substances present*

PID instruments are nonspecific

- *Reading is sum of signals of all detectable substances present, also:*
- *Reading is function of their varying ionization potentials and other physical properties*
- *PID readings always relative to gas used to calibrate detector*
- *Equivalent concentrations of gases other than the one used to calibrate the instrument may not produce equivalent readings!*

Response is Relative to Gas Measured

- *Reading of 10 ppm only indicates ion current equivalent to that produced by 10 ppm concentration calibrant*
- *Amount of different contaminant needed to produce same current may be larger or smaller than concentration of calibrant*
- *Since PID readings always relative to calibrant, should be recorded as ppm-calibration gas equivalent units, or PID units, never as true 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 Correction Factors

- *Correction factors are APPROXIMATE values*
  - *Correction Factor (CF) is measure of sensitivity of PID to specific gas*
  - *CFs do not make PID specific to a chemical, only correct the measurement scale to that chemical*
  - *CFs allow calibration on inexpensive, non-toxic "surrogate" gas (like isobutylene)*
  - *Most manufacturers furnish tables, or built-in library of CFs to correct or normalize readings when contaminant is known*
  - *Instrument able to express readings in parts per million equivalent concentrations for the contaminant measured*

CF measures sensitivity

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

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 your PID*
  - *ONLY USE A CORRECTION FACTOR FROM THE MANUFACTURER OF YOUR PID!*

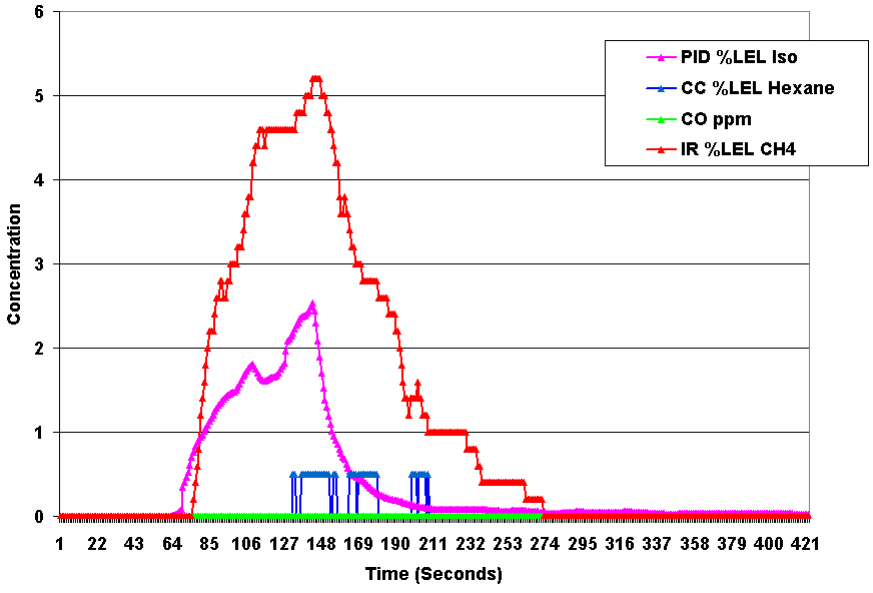
Correction Factors (10.6 eV Lamp)

Examples of manufacturer PID correction factors (10.6 eV lamp)					
Gas / vapor	RAE	BW	Ion	GfG	IE (eV)
Acetaldehyde	5.50	4.60	4.90	5.40	10.21
Acetone	1.10	0.90	0.70	1.20	9.69
Ammonia	9.70	10.60	8.50	9.40	10.20
Benzene	0.50	0.55	0.50	0.53	9.25
Butadiene	1.00	0.90	0.85	0.69	9.07
Diesel fuel	0.80	0.93	0.75	0.90	n/a
Ethanol	12.00	13.20	8.70	10.00	10.48
Ethylene	10.00	11.00	8.00	10.10	10.52
Gasoline	0.90	0.73	1.10	1.10	n/a
n-Hexane	4.30	4.00	3.30	4.50	10.18
Jet fuel (JP-8)	0.60	0.51	0.70	0.48	n/a
Kerosene	n/a	1.11	0.80	n/a	9.53
Methyl-ethyl-ketone (MEK)	0.90	0.78	0.77	0.90	9.53
Naptha (iso-octane)	1.20	1.20	1.10	1.30	9.82
Styrene	0.40	0.45	0.45	0.40	8.47
Toluene	0.50	0.53	0.51	0.53	8.82
Turpentine	0.40	0.45	0.45	0.45	n/a
Vinyl chloride	2.00	2.19	2.20	1.80	10.00
Xylene (mixed isomers)	0.40	0.50	0.43	0.50	8.50

Choosing the best sensor configuration

- *Multi-sensor instruments can include up to seven channels of real-time measurement*
- *Available sensors for combustible gas and VOC measurement::*
  - *CC %LEL*
  - *IR %LEL*
  - *IR %Vol*
  - *Thermal Conductivity %Vol*
  - *Electrochemical toxic*
  - *PID*

Test run# 1: PID, CC LEL, IR LEL and CO sensors exposed to diesel vapor



Selection matrix for Sensors for measurement of combustible gas and VOCs

	Able to detect LEL range C1 – C5 hydro-carbon gases (methane, ethane, propane, butane, pentane and natural gas)	Able to detect LEL range C6 – C9 hydro-carbon gases (hexane, heptane, octane, nonane)	Able to accurately detect LEL range heavy fuel vapors (e.g. diesel, jet fuel, kerosene, etc.)	Able to detect heavy fuel vapors in low ppm range (e.g. diesel, jet fuel, kerosene, etc.)	Able to use in low oxygen atmospheres	Vulnerable to sensor poisons (e.g. silicones, phosphine, tetraethyl lead, H2S, etc.)	Able to use for high range combustible gas measurement (100% LEL and higher)	Able to measure H2
Standard Pellistor type LEL sensor	Yes	Yes	No	No	No	Yes	No	Yes
NDIR combustible gas sensor	Yes	Yes	Yes	Yes*	Yes	No	Yes	No
PID (with standard 10.6 eV lamp)	No	Yes**	Yes**	Yes	Yes	No	No	No
Electrochemical H2 sensor	No	No	No	No	Yes	No	No	Yes
Thermal Conductivity Sensor	Yes	Yes	No	No	Yes***	No****	Yes	Yes

Overview of G450 / G460 Features

G450 Confined Space Gas Detector

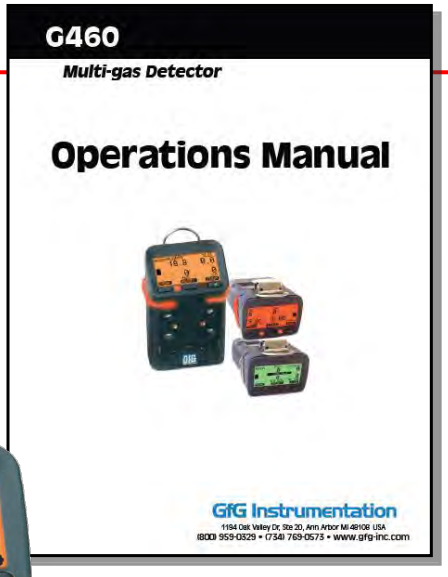
- *One to four sensors*
- *Full 3-year warranty on all sensors*
- *Optional 6-year warranty on all sensors*
- *O2 sensor rated for continuous use in – 30°C temperatures*
- *Interchangeable reechargeable (NiMH) or alkaline battery packs last 25 hours per charge*
- *Super durable IP-67 water resistant design*
  - *Only $695.00 USD list price (alkaline)*
  - *Only $745.00 USD list price (rechargeable)*

G460 Multi-gas Monitor

- *Up to SEVEN channels detection*
- *Comprehensive range of interchangeable smart sensors:*
  - *LEL, O2, CO, H2S: 3-year warranty*
  - *Infrared combustible gas: 3-year warranty*
  - *Infrared CO2: 3-year warranty*
  - *Most other substance-specific EC toxic: 2-year warranty*
  - *PID lamp: 1-year warranty*

Easy to use!

- ***Basic operation is extremely simple***
- ***Single on-off button all that is needed for most day to day use***
- ***Every instrument shipped complete with operations manual***



Three color "Traffic Signal" display

- ***Back lit three-color full graphics LCD***
- ***Top mounted display with wrap around (360º) LED alarm indicator***
- ***LCD includes flip and zoom functions***

Rugged design

- ***Rugged, double shot molded housing includes integral rubberized boot***
- ***Durable high tension steel alligator belt clip***

G460 Multi-gas Monitor

- ***Standard G460 housing color now "GfG Blue"***
- ***Optionally still available in "GfG Black"***

G450 / G460 Multi-Gas Detector

- *Interchangeable rechargeable (NiMH) or alkaline battery packs last up to 25 hours per charge*
- *Top-mounted, three color, full graphics LCD*
- *Durable IP-67 water resistant design*
- *O2 sensor rated for continuous use in –30°C temperatures*

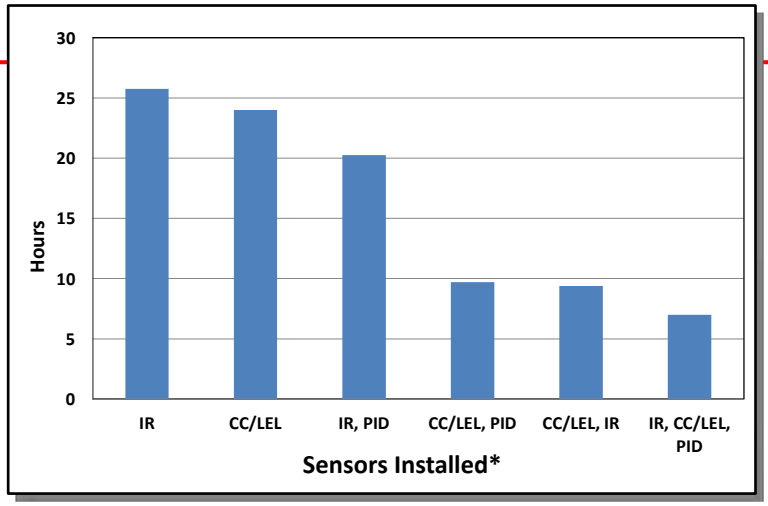
G450 / G460 battery packs

- *Interchangeable rechargeable (NiMH) and alkaline battery packs last up to 25 hours*
- *NiMH batteries provide excellent cycle life and low temperature performance*
- *NiMH battery packs warranted for 2-years*
- *Typical run-time after two years for properly maintained NiMH battery packs is usually around 16 hours*

Rechargeable battery pack

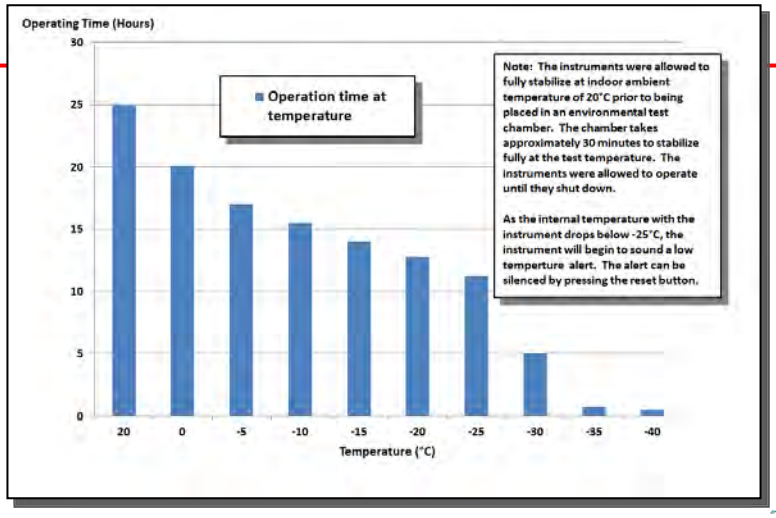
- *Available with optional built-in flashlight LEDs*

Expected G450 / G460 run times



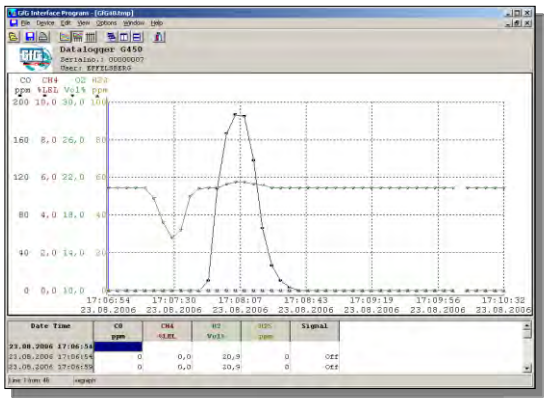
*All configurations include O2 and CO/H2S sensors as well as the listed "high power" sensors

Expected G450 run times as function of temperature



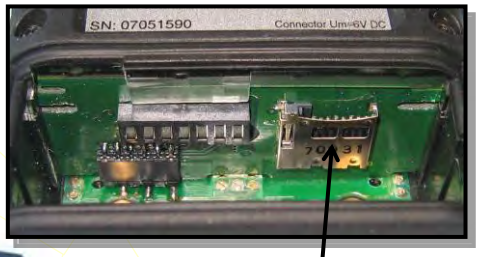
Datalogging Standard

- ***Mode:***
  - ***Average***
  - ***Peak***
  - ***Instantaneous***
- ***Interval:***
  - ***1 sec. – 60 min.***
- ***Internal capacity:***
  - ***1,890 intervals***
  - ***63 hours continuous at 2 min. Interval***
- ***G460:***
  - ***Built-in expansion slot for 2GB additional data storage capacity***



G460 Optional Extended Datalogging Storage Capacity

- *Built-in slot for optional high capacity extended memory card*



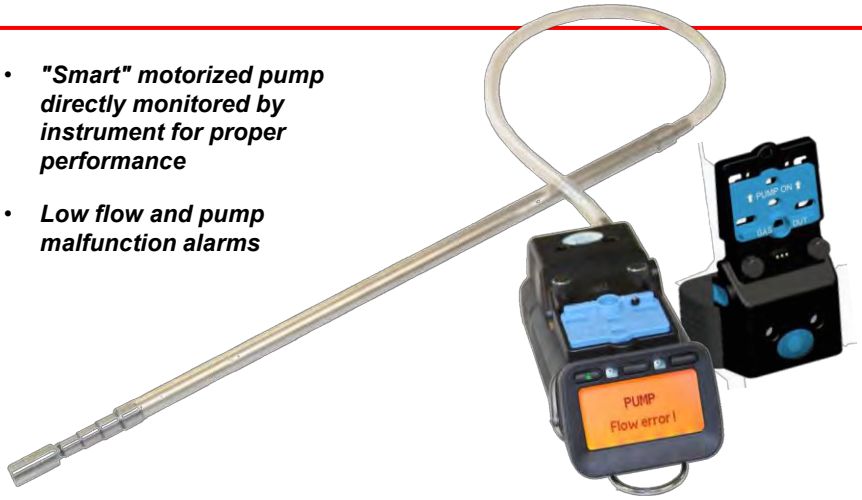
Memory expansion card slot

G450 / G460 Motorized Pump

- *Powerful motorized "smart pump" with its own battery pack*
- *Sliding up the shutter turns on the pump and covers the diffusion ports*
- *Motorized pump can be attached or removed from instrument as needed*

G450 / G460 Motorized Pump

- *"Smart" motorized pump directly monitored by instrument for proper performance*
- *Low flow and pump malfunction alarms*



G450 / G460 Drop-in Charger

- *Smart charger includes trickle charge mode to prevent damage to battery pack due to overcharging*
- *Available in single and double versions*
- *Available for use with 12 VDC vehicle charging system*

Optional G450 / G460 Drop-in Charger for Pump Equipped Instruments

- *Charger simultaneously charges both pump AND instrument*
- *Available for use with 12 VDC vehicle charging system*

G450 / G460 Five-Unit Multi-Charger

- *Five instrument multi-charger*

Five instrument multi-charger

- *Can be substituted in place of standard cradle chargers with orders of 5 or more instruments*

Other accessories

- *Calibration adapters*
- *Sampling probes*
- *Leather holsters*
- *Calibration kits*

Use TS-400 Test Station for daily bump check

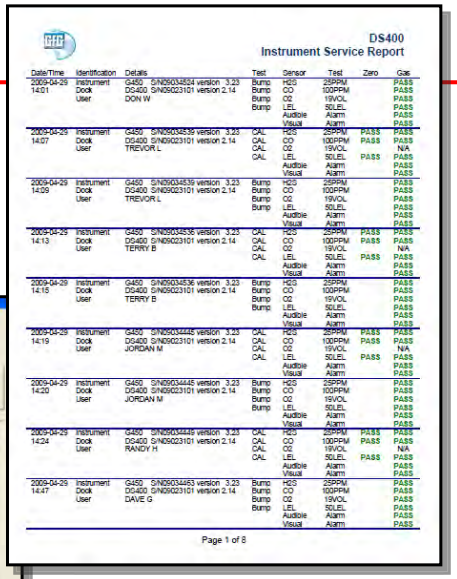
- *Standalone operation - No PC required!*
- *Automatic bump-test only*
- *Success / failure indication after each test*
- *Economic use of test gas*
- *Easy collection of unit test and logged data*

Use DS400 Docking Station for daily bump check and / or periodic calibration

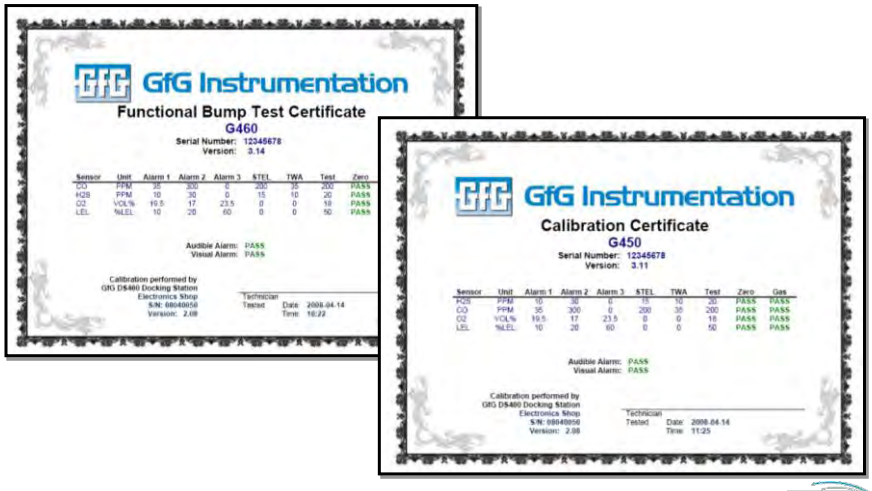
- *Standalone operation:*
- *No PC required*
- *Automatic bump-test*
- *Automatic span calibration*
- *Success / failure indication after each test*
- *Economic use of test gas*
- *Easy collection of unit test and logged data*
- *Reduced maintenance cost*

Comprehensive Test Reports

- ***Easy to generate custom test reports***



Automatically generate calibration and bump test certificates

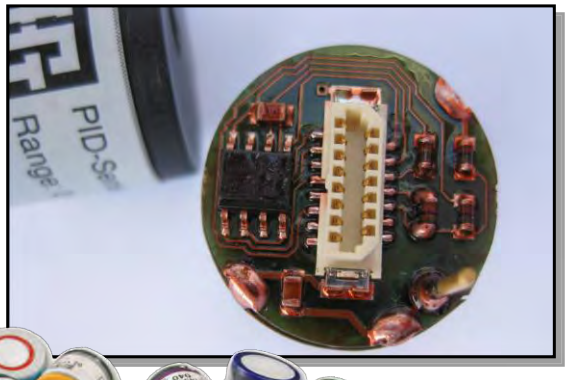


Accessories included with every instrument

- *Instrument with CO, H_2S, LEL and O_2 sensors (installed)*
- *Operations manual*
- *Battery pack (installed)*
  - *Rechargeable NiMH or*
  - *Alkaline*
- *Charging cradle (when instrument has rechargeable battery pack)*
- *110 VAC wall-cube power source*
- *Calibration adapter*

Traditional Electrochemical Toxic Gas Sensors

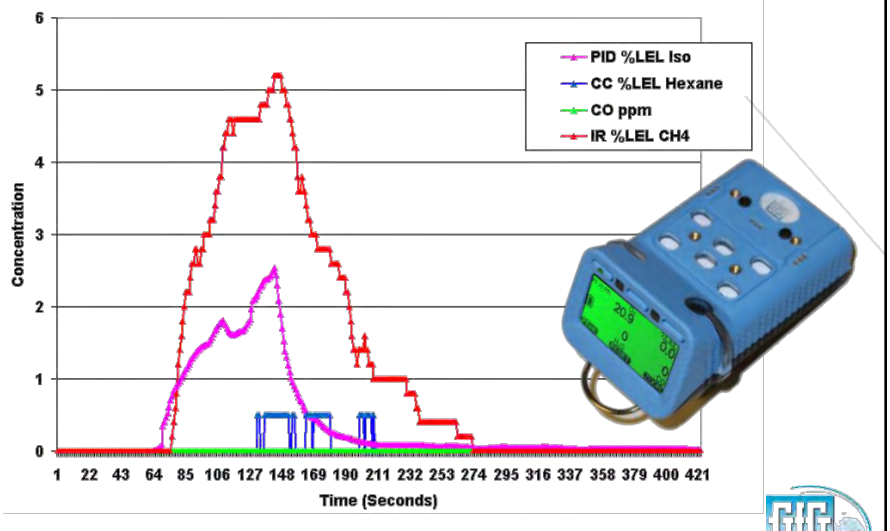
- *More types of sensors available every year*
- *Toxic gas sensors designed to detect target gases at ever lower concentrations*



G460 Interchangeable Plug-and-Play Smart Sensors

- **Available sensors include:**
  - O_2
  - Catalytic LEL
  - Infrared LEL
  - Infrared CO_2
  - CO
  - H_2S
  - COSH
  - PID
  - SO_2
  - Cl_2
  - ClO_2
  - NH_3
  - H_2
  - PH_3
  - HCN
  - NO
  - NO_2
  - HCL
  - HF
  - EtO
  - O_3
  - $COCl_2$
  - HBr
  - THT
  - and more!

G460 has the flexibility to support the right sensor technology for the job!



GfG wins hands down when it comes to features AND three year cost of ownership!

Sales Support: www.Goodforgas.com

- ***Data sheets***
- ***Price lists***
- ***Manuals***
- ***Application Notes***
- ***Product images***
- ***Print ads ...and more!***

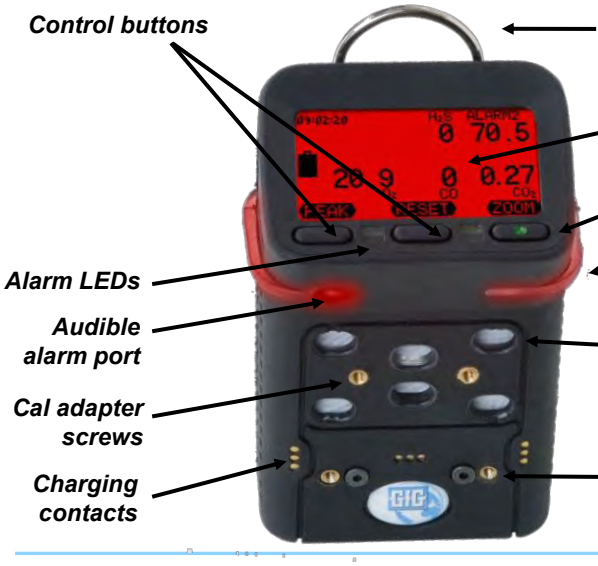
G450 / G460 Basic Operation

Basic operation

- *Basic operation is extremely simple*
- *Single on-off button all that is needed for most day to day use*

Read and understand the operations manual before use!

External features and controls



Battery Pack Location

Turning the instrument on

- *Verify proper performance by performing bump test before each day's use*
- *Make sure instrument located in fresh air before turning on*
- *Press the right hand button to turn on*

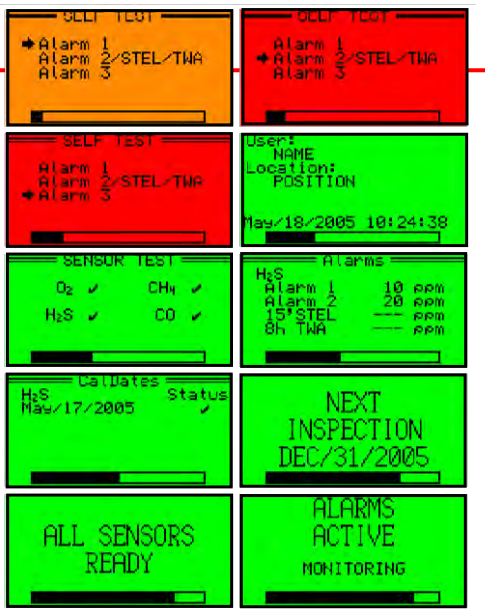
On / Off button (one with green indented dot)

Verifying firmware version

- *The first screen in the start-up sequence shows the software version (firmware) currently installed*

Startup sequence

- *After turning on instrument will display sequence of screens*
  - *Status of sensors*
  - *Alarm settings*
  - *Calibration and bump test due dates*
- *Audible and visual alarms will briefly activate*
- *Count-down indicates when G460 ready to use*
- *Instrument will display alarm notification if bump test or calibration is overdue*



Instrument start up

- *If the instrument displays a "Bump test" or "Calibration" warning during startup, press "NEXT" to acknowledge and continue*

  Do not use the instrument to monitor for gas until the required procedure is completed!
- *Check battery status when startup is complete*
- *Verify that the readings stabilize at fresh air values (20.9% O_2, 0% LEL, 0 ppm toxic gas) and perform a fresh air Autocal adjustment if needed*
- *Use the Docking Station or manually perform the required Bump Test or Calibration procedure*

"Bump test" and "Calibration" overdue alarms

- *The audible and LED alarms are activated and a warning message indicates the "Bump test" or "Calibration" due date has been exceeded*
- *The warnings can be acknowledged by pressing the "NEXT" button, in which case the instrument continues the startup sequence*
- *The alarms will continue to be displayed every time the instrument is turned on until they are cleared*
- *The "Bump test" overdue alarm can only be cleared by using a Docking Station*
- *The "Calibration" alarm can be cleared either by using a Docking Station, or performing a full manual calibration on the instrument*

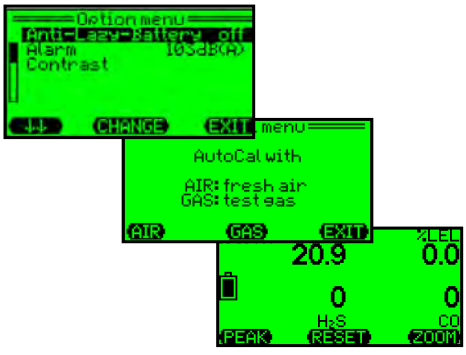
Turning the instrument off

- *Press and hold down the right hand "Zoom" button for 5 seconds to turn off*
- *LCD will count down (3…2…1)*
- *Release button when steady tone indicates shut-down is complete*

On / Off ("Zoom") button

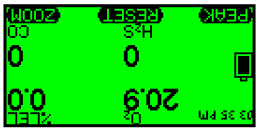
Function of buttons

- *The "name" and function of the control buttons change depending on what you are doing or seeing on the display*



LCD features

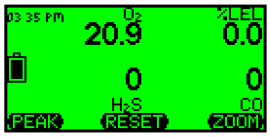
- *Pressing any button will causes display backlight to be activated*
- *Press the "Zoom" button once to magnify readings, press "Zoom" again to see next gas*
- *Pressing "Peak" and "Zoom" at same time will "flip" display*



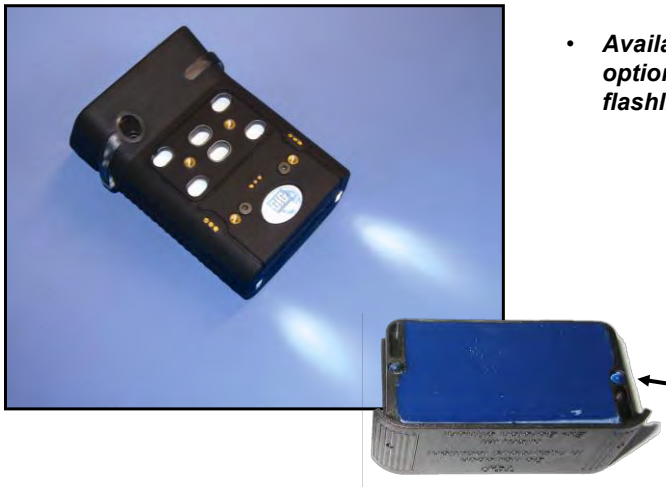
LCD features

- ***Pressing "Reset" and "Zoom" at same time puts instrument directly into "AutoCal" mode***

AIR	- AutoCal® with fresh air
GAS	- AutoCal® with test gas
EXIT	- Back to main menu



Rechargeable battery pack

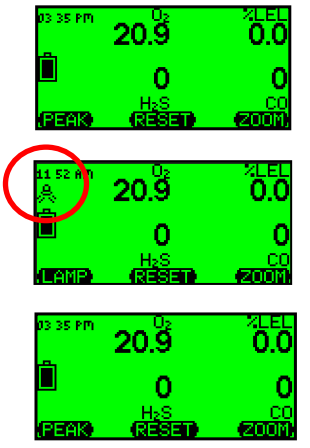


- ***Available with optional built-in flashlight LEDs***

LED location

To turn on LED flashlight

- *From normal operation:*
  - *Press and hold "Peak" until the soft key changes name to "Lamp" and lamp icon shows in display*
  - *LEDs will remain lit for 60 seconds, then turn off*
  - *Press "Lamp" to turn off sooner*



Instrument readings and alarms

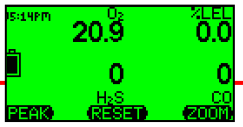
- *LEL:*
  - *Readings in 0.5% LEL increments*
- *H_2S:*
  - *Standard H_2S sensor:*
    - *Readings in 0.1 ppm increments*
  - *COSH sensor:*
    - *H_2S readings in 0.2 ppm increments*
- *CO:*
  - *Readings in 1.0 ppm increments*
- *O_2:*
  - *Readings in 0.1% volume increments*

G450 / G460 alarms

Alarm Type	Sensors	Number of Alarms	Description
Instantaneous Value (AL)	Oxygen Combustible gases Toxic gases	3 3 2	An instantaneous alarm is activated immediately if the gas concentration exceeds or falls below a pre-set threshold. The alarm values are adjustable.
Short Term Value (STEL)	Toxic gases	1	The short-term value (STEL) is the average concentration over a short period of time (e.g. 15 minutes). The STEL alarm is not latching; it resets automatically as soon as the concentration falls below the threshold.
Long Term Value (TWA)	Toxic gases	1	The long-term value (TWA) refers to an 8-hour shift and calculates the average concentration. The TWA alarm cannot be reset. It is only de-activated if the detector is switched off.

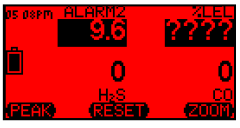
Effects of O_2 concentration on combustible gas readings

- ***LEL readings may be affected if levels of O_2 are higher or lower than fresh air***
- ***The standard catalytic LEL sensor requires a minimum level of 10% oxygen to read LEL***
- ***If the O_2 concentration is too low the LEL reading will be replaced with question marks***



Readings in fresh air

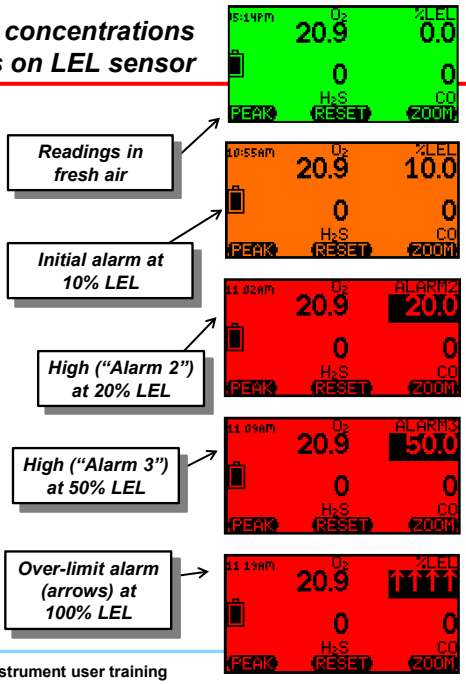
Readings in O_2 deficient air



Readings when O_2 too low for LEL sensor

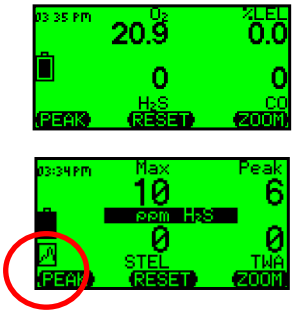
Effects of high concentrations of gas on LEL sensor

- *Additional concerns when using standard catalytic LEL sensors:*
  - *Work is not permitted in areas where the concentration of gas exceeds safety limits!*
  - *If the explosive gas concentration is too high there may not be enough oxygen for the LEL sensor to detect properly*
  - *Concentrations above 100% LEL can damage the LEL sensor*



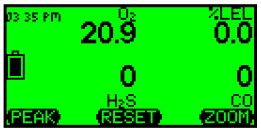
Peak Reading Mode

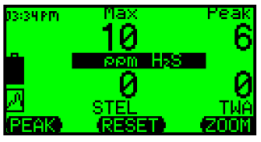
- *Main screen shows the current gas concentrations*
- *Press "Peak" once put instrument into "Peak" reading mode*
- *Icon in display indicates when in peak reading mode*
- *Press "Reset" to clear the peak readings*
- *Press "Peak" to return to normal operation*
- *Note: after 15 minutes G450 returns to normal gas reading screen*



Clearing "Peak Mode" readings

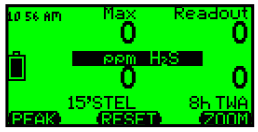
- *"Peak Hold" function shows most significant values ONLY between the time "Peak" button is first pushed and the next time it is pushed to clear the "Peak" readings*
- *Pushing "Peak" again clears the displayed "Peak Mode" readings and returns instrument to normal operation*
- *Clearing "Peak Hold" readings DOES NOT clear or reset the Max, STEL or TWA readings in the instrument memory*

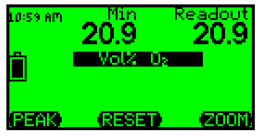




Viewing Peak, STEL and TWA readings for entire monitoring interval

- *The instrument can also display Peak, STEL and TWA readings for the entire monitoring interval (the period of time that the instrument has been turned on)*
- *Press "Zoom" to make numbers larger, then press and hold "Zoom" for approximately 2 seconds (till instrument beeps)*
- *Display will now show Max, STEL, TWA for toxic sensors; Max combustible gas, and Min O2*
- *Press "Zoom" to advance from one sensor to the next*





G450 / G460 battery packs

- *Interchangeable rechargeable (NiMH) and alkaline battery packs last up to 25 hours*
- *NiMH batteries provide excellent cycle life and low temperature performance*
- *NiMH battery packs warranted for 2-years*
- *Typical run-time after two years for properly maintained NiMH battery packs is usually around 16 hours*

G450 / G460 Drop-in Charger

- *Smart charger includes trickle charge mode to prevent damage to battery pack due to overcharging*
- *Available in single and double versions*
- *Available for use with 12 VDC vehicle charging system*

Optional G450 / G460 Drop-in Charger for Pump Equipped Instruments

- *Charger simultaneously charges both pump AND instrument*
- *Available for use with 12 VDC vehicle charging system*

G450 / G460 Charging Cycle

- *GfG smart chargers begin the charging cycle in the "fast charging mode", then switch to "trickle charge mode" when the battery is charged to 90% of its full capacity*
- *Completely discharged batteries may require up to 6 hours to reach the trickle charge stage*

Note: If possible, leave the instrument in the charger for an additional one or two hours after reaching the trickle charge stage to reach 100% of the charge capacity of the battery

G450 / G460 Charging Cycle

- *The green LED in the "single" charger cradle indicates power*
- *A solid amber LED indicates fast charging*
- *A flashing amber LED indicates trickle charging*
- *The instrument display indicates how long the instrument has been in each stage of the cycle*

Solid amber indicates fast charging, flashing amber indicates trickle

Changing battery packs

NiMH: Black

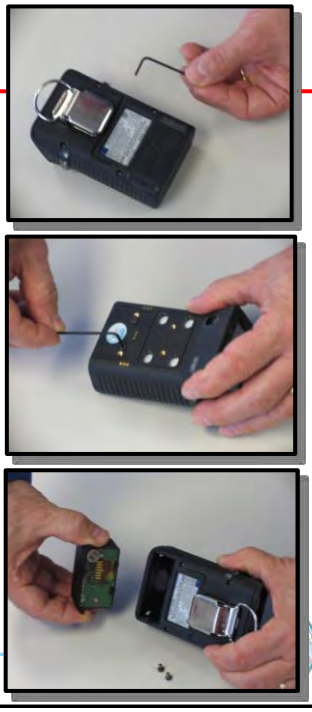
Alkaline: Gray

Changing battery packs

- *Use the hex wrench tool to loosen and remove the two screws securing the battery pack to front of the instrument housing*
- *GENTLY remove the battery pack from the instrument*

NOTE: USE YOUR FINGERS TO REMOVE THE BATTERY PACK FROM THE INSTRUMENT

NEVER USE A SCREWDRIVER OR OTHER HARD TOOL TO REMOVE THE BATTERY PACK



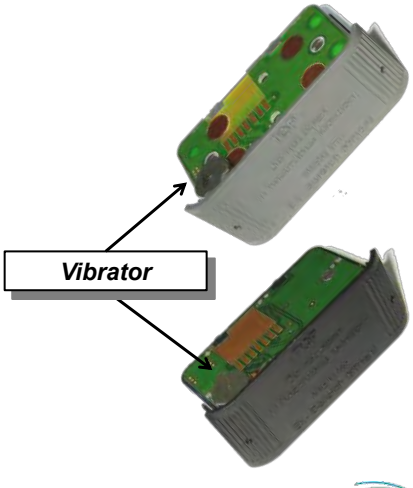
Changing battery packs

- *Make sure that the vibrator (the flat disc on the top of the battery pack is) is at the top when the battery pack is reinserted into the instrument*

DO NOT FORCE WHEN INSERTING THE PACK INTO THE HOUSING!

- *Reinstall and tighten the screws*

MAKE SURE SCREWS ARE SECURE BUT DO NOT OVERTIGHTEN!



Voltage depression due to over-charging

- *NIMH batteries do not develop "memories", however, if they are not exercised they may become "lazy"*
- *Even though the normal amount of power is stored the battery, the peak voltage in "lazy" batteries drops more quickly than usual*
- *Voltage depression is caused by the formation of small crystals of electrolyte on the plates, increasing resistance and lowering the voltage of some individual cells in the battery*
- *To the user it appears the battery is not holding its full charge; to the instrument the rapid drop in voltage indicates that the batteries are about to run out of energy*
- *Exercising the battery by putting it through a deep-discharge cycle can break down the crystals, and improve or restore the run time of the instrument*

"Anti-lazy battery" deep-discharge cycle

- *Fully charged instruments that fail to operate for the expected time should be exercised by means of the "anti lazy battery" deep discharge cycle*

Note: Instruments that are left on the charger for prolonged periods between use may benefit from being exercised by being deep discharged on a quarterly basis

Charger cradle hardware compatibility

- *G450 and G460 instruments with version 3.41 and higher firmware have enhanced "anti-lazy battery" as well as other features*
- *GfG recommends updating your instrument firmware to take advantage of these enhanced features*
- *To take full advantage of the latest anti-lazy battery options it is also necessary to have the latest version charger cradle and power adapter*

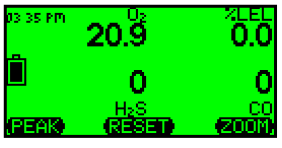
Note: Charger cradle and power adapters sold prior to October, 2011 can be updated at the GfG factory in Ann Arbor to the latest configuration

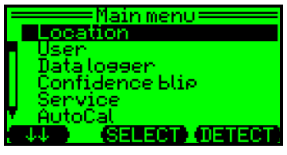
Cradle serial numbers ending in "D" indicate the latest version

Power adapter must be equipped with "stereo" type jack with two black stripes

Main menu screen

- *Press and hold down "Reset" button until "Main menu" choices appear:*
  1. *Location (use to enter a location name)*
  2. *User (use to enter a user ID number)*
  3. *Datalogger (use to adjust datalog interval)*
  4. *Alarm clock (use to activate a periodic alarm based on the clock time)*
  5. *Service (use to access the "Service Menu")*
  6. *AutoCal® (use to make either fresh air or span calibration adjustment)*
  7. *Options (use to adjust display contrast, alarm loudness, confidence beep, or activate "Anti Lazy Battery" option)*
  8. *Pump (use to review pump status of motorized pump)*





One-time deep discharge cycle for NiMH battery pack

- *From "Option Menu" choose "Anti-Lazy-Battery"*
- *Press "Change" to turn on the one-time deep discharge feature*
- *Display will show "1X" instead of "Off"*
- *Press "Exit" to return G450 to normal operation*

DO NOT TURN THE INSTRUMENT OFF!

- *Allow to run until battery completely drained, then recharge normally, OR*
- *When down to last 10% of battery place instrument in charger*

Do not place in charger until battery icon shows it is down to the last 10% remaining voltage

- *Instrument will complete anti-lazy battery deep discharge, then charge normally*

Automatic deep discharge cycle

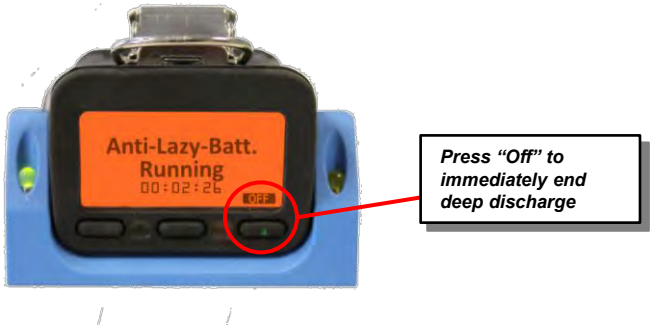
- *It is possible to program the instrument so the deep discharge cycle is always automatically activated whenever the instrument is placed in the charger when the battery is below 10% remaining voltage*
- *From "Options" choose "Anti-Lazy-Battery" then press "Change" to activate the one-time deep discharge cycle (display will show "1X")*
- *Press "Change" again to choose "Days"*
- *Anytime the instrument is placed in the charger when there is less than 10% remaining voltage the deep discharge cycle will be activated automatically*

Limiting automatic deep discharge cycle to certain days

- *Since deep-discharge can take up to 20 hours to complete, it may be advisable to limit automatic deep-discharge to certain days of the week (i.e. enabling the feature for Fridays to give the instrument a full weekend to complete discharging and recharging)*
- *Press the "down arrow" key to highlight the "Anti-Lazy days" choice, then press "Change"*
- *The instrument will display the days of the week*
- *Select the desired days for the automatic activation of this feature, then "Exit" to return to normal operation*

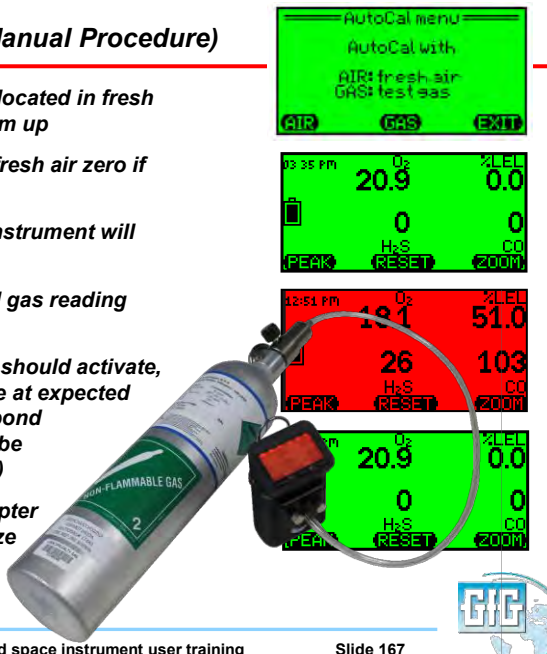
Automatic deep discharge cycle

- *Pressing "Off" while the instrument is in the charger immediately ends the deep-discharge cycle, and returns the instrument to normal charging*



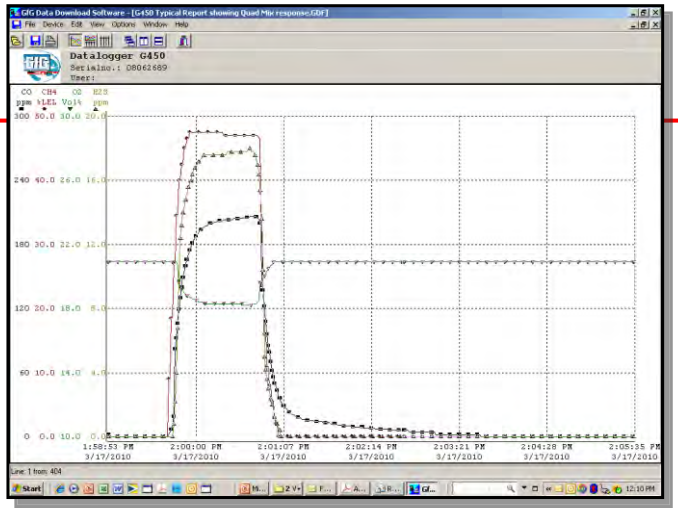
Bump Test (Manual Procedure)

- *Make sure the instrument is located in fresh air, turn on, and allow to warm up*
- *Note readings, and perform fresh air zero if necessary*
- *Attach calibration adapter; instrument will display "AutoCal menu"*
- *Press "Exit" to show normal gas reading screen*
- *Flow gas to sensors; alarms should activate, and readings should stabilize at expected values (if sensors fail to respond properly, instrument should be calibrated before further use)*
- *Turn off gas, remove cal adapter and allow readings to stabilize at fresh air values*



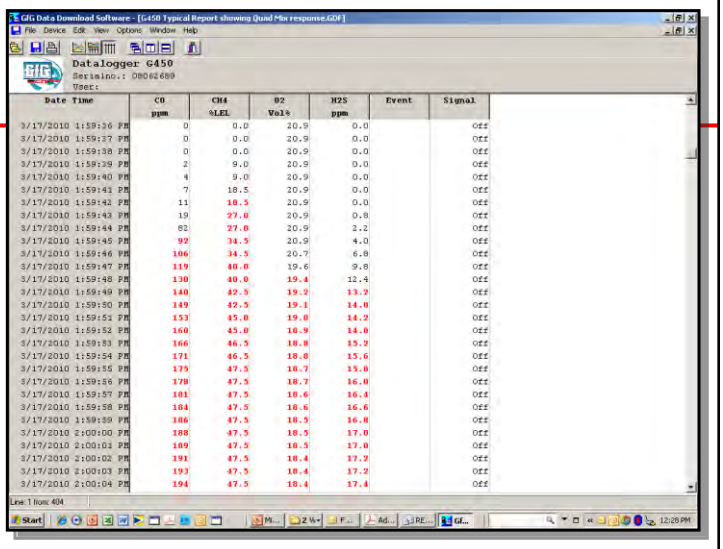
Bump Test

- *Response of sensors to Quad Mix (graphs)*
- *Readings recorded while instrument operated in normal gas reading mode*
- *Simultaneous response to all four gases, as well as match between cal gas concentrations and readings*



Bump Test

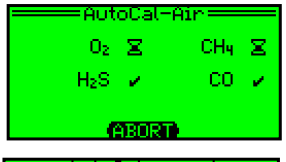
- *Response of sensors to Quad Mix (table)*
- *Readings recorded while instrument operated in normal gas reading mode*
- *When a sensor is in alarm readings are recorded in red*



Date Time	CO ppm	CH4 %LEL	O2 Vol%	H2S ppm	Event	Signal
3/17/2010 1:59:36 PM	0	0.0	20.9	0.0		Off
3/17/2010 1:59:37 PM	0	0.0	20.9	0.0		Off
3/17/2010 1:59:38 PM	0	0.0	20.9	0.0		Off
3/17/2010 1:59:39 PM	2	9.0	20.9	0.0		Off
3/17/2010 1:59:40 PM	4	9.0	20.9	0.0		Off
3/17/2010 1:59:41 PM	7	18.5	20.9	0.0		Off
3/17/2010 1:59:42 PM	11	18.5	20.9	0.0		Off
3/17/2010 1:59:43 PM	19	27.0	20.9	0.8		Off
3/17/2010 1:59:44 PM	82	27.0	20.9	2.2		Off
3/17/2010 1:59:45 PM	92	34.5	20.9	4.0		Off
3/17/2010 1:59:46 PM	106	34.5	20.7	6.8		Off
3/17/2010 1:59:47 PM	119	40.0	19.6	9.0		Off
3/17/2010 1:59:48 PM	130	40.0	19.4	12.4		Off
3/17/2010 1:59:49 PM	140	42.5	19.2	13.2		Off
3/17/2010 1:59:50 PM	149	42.5	19.1	14.0		Off
3/17/2010 1:59:51 PM	153	45.0	19.0	14.2		Off
3/17/2010 1:59:52 PM	160	45.0	18.9	14.8		Off
3/17/2010 1:59:53 PM	166	46.5	18.8	15.2		Off
3/17/2010 1:59:54 PM	171	46.5	18.8	15.6		Off
3/17/2010 1:59:55 PM	175	47.5	18.7	15.8		Off
3/17/2010 1:59:56 PM	179	47.5	18.7	16.0		Off
3/17/2010 1:59:57 PM	181	47.5	18.6	16.4		Off
3/17/2010 1:59:58 PM	184	47.5	18.6	16.6		Off
3/17/2010 1:59:59 PM	186	47.5	18.5	16.8		Off
3/17/2010 2:00:00 PM	188	47.5	18.5	17.0		Off
3/17/2010 2:00:01 PM	189	47.5	18.5	17.0		Off
3/17/2010 2:00:02 PM	191	47.5	18.4	17.2		Off
3/17/2010 2:00:03 PM	193	47.5	18.4	17.2		Off
3/17/2010 2:00:04 PM	194	47.5	18.4	17.4		Off

Manual AutoCal

- *AutoCal allows instrument to be "Fresh air" or "Calibration" (span) adjusted if needed*



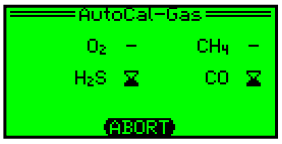
AIR - AutoCal® with fresh air
GAS - AutoCal® with test gas
EXIT - Back to main menu

Attach Cal Cap to Enter Fresh Air and Span "AutoCal"

Attach cal cap to unit; instrument automatically enters "AutoCal" menu

Choose ZERO or CAL and apply gas (if calibrating), e.g. an H_2S/CO mix.

Adjustment is automatic



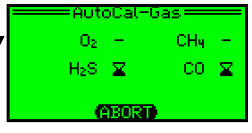
Display shows when cal adjust has been successfully completed

Can also enter "AutoCal" mode by pushing "Reset" and "Zoom" buttons at same time

Push "Reset" and "Zoom" at same time; instrument automatically enters "AutoCal" menu

Choose ZERO or CAL and apply gas (if calibrating), e.g. an H_2S/CO mix.

Adjustment is automatic



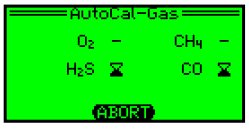
Display shows when AutoCal adjust has been successfully completed

Calibration gas concentrations

- *Best to use the default cal gas concentrations*
- *Default GfG concentrations used to calibrate instrument:*
  - *200 ppm CO*
  - *20 ppm H_2S*
  - *50% LEL methane (CH_4)*
- *If you use different concentrations you must change instrument settings!*

What should you do if you fail AutoCal adjustment?

- *AutoCal adjusts all of the sensors that can be adjusted based on the calibration gas being used*
- *The display will show an "Error" for any sensors that were not successfully adjusted*
- *The most common reasons for failing AutoCal adjustment are:*
  - *Forgetting to attach the cal adapter*
  - *Forgetting to turn on the flow of gas*
  - *Empty calibration gas cylinder*
  - *Wrong cylinder / wrong concentration(s) in calibration gas*
  - *Gas has expired dating and is no longer usable*
- *Before giving up, check the gas and fittings and try again*

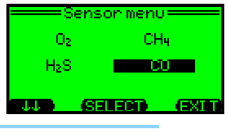


What if you check the gas and fittings but still fail AutoCal adjustment?

- *To avoid accidentally using the wrong cal gas, or zeroing the instrument in the presence of contaminants;*
- *AutoCal has a maximum permitted change in adjustment between one fresh air zero, or one span calibration and the next*
- *If the change between the zero or span setting exceeds this maximum, the instrument will not properly adjust*
- *In this case you will need to perform a single-sensor calibration on the sensor or sensors that have failed to calibrate properly*

Single sensor calibration procedure (part 1)

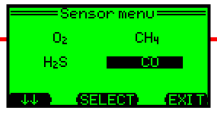
- *Use single sensor calibration procedure whenever you need to calibrate one sensor at a time*
- *Press and hold "Reset" button to show the "Main Menu" then chose "Service"*
- *For "Security Code" use "1100" as the password*
- *Choose "Sensors" then select the sensor that you intend to calibrate*

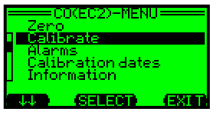


Make sure to use "1100" as password.

"1100" is a special password that allows a wider maximum calibration adjustment window.

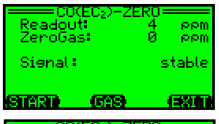
Single sensor calibration procedure (part 2)

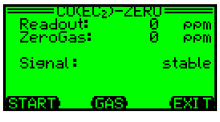




- *A screen will show the menu choices for the selected sensor*
- *If the sensor needs to be fresh air adjusted choose "Zero"*
- *If the sensor does not need to be fresh air adjusted choose "Calibrate"*

Single sensor calibration procedure (part 3)



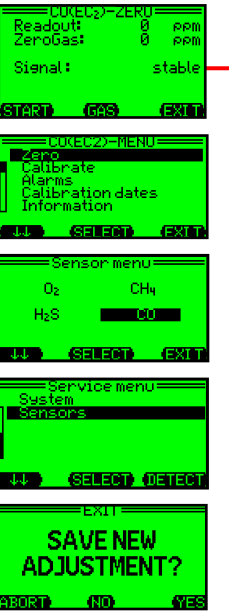


- *To perform a fresh air zero:*
  - *Make sure the sensor is exposed to fresh, contaminant free air*
  - *Make sure to remove the cal adapter if you are using the surrounding air to adjust the sensor*
  - *The "Zero" screen will show the current reading*
  - *Press "Start" to begin the fresh air adjustment*
  - *An "OK" indicates when the procedure is complete, after which the screen returns to the "Zero" screen*

You MUST save the results of the fresh air or calibration adjustment or they will not be saved to the instrument's memory!

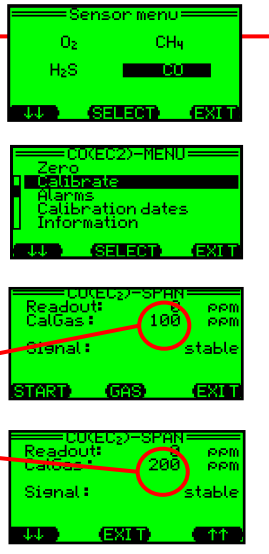
Saving single-sensor "Zero" and "Calibration" results (part 4)

- ***If you do not deliberately save the results, after a few minutes the instrument will return to normal operation and the results will not be saved!***
- ***Press "Exit" to save the results and return to normal operation***
- ***Each time you press "Exit" you move up one level in the instrument program***
- ***The final screen will ask whether you want to "Save new adjustment?"***
- ***Press "Yes" to update the instrument memory***



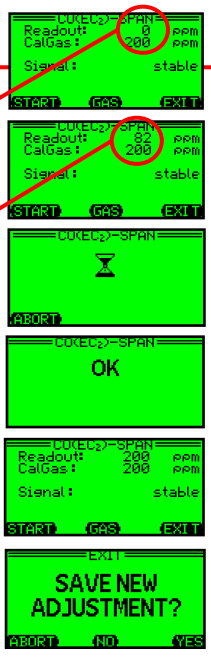
Single sensor calibration procedure (part 5)

- ***To perform a span Calibration:***
  - ***Choose the sensor to be calibrated***
  - ***Choose "Calibrate" from the menu***
  - ***Make sure the calibration adapter, calibration gas and regulator are attached to the instrument***
  - ***The "Span" calibration screen shows the "CalGas" concentration that the instrument will use to adjust the sensor***
  - ***Verify the concentration of gas in the cylinder matches the "CalGas" value***
  - ***If needed, you can adjust the "CalGas" value by selecting "Gas" then using the arrow (↑↑ or ↓↓) buttons to change the concentration***
  - ***Press "Exit" after you finish adjusting the "CalGas" concentration***



Single sensor calibration procedure (part 6)

- *To perform a span Calibration:*
  - *The "Readout" shows the current sensor reading*
  - *Open the regulator valve to begin flowing gas to the sensor*
  - *The "Readout" number will begin to rise as the sensor is responds to the gas*
  - *Press "Start" to begin the calibration adjustment*
  - *The "Span" calibration screen will show an hour-glass icon while the sensor is being adjusted, then an "OK" message when the adjustment is complete*
  - *Press "Exit" to return the instrument to normal operation.*
  - *Remember to "Save" the new adjustment or the results of the calibration will not be updated to the instrument memory*



DS-400 Docking Station for daily bump check and / or periodic calibration

- *Standalone operation:*
  - *No computer required!*
- *Docking station controlled by instrument's control buttons:*
  - *Push "Test" for Bump Test*
  - *Push "Cal" for Auto Cal*
  - *Push "Cancel" to charge only*

DS-404 Multi-inlet Docking Station for bump check and periodic calibration

- *Inlets for 4 cylinders of gas*
- *Automatic Bump and Cal for 5, 6 and 7 channel instruments*
- *Supports:*
  - *Quad mix (O_2, LEL, CO, H_2S)*
  - *5-mix with SO_2*
  - *5-mix with CO_2*
  - *Isobutylene*
  - *HCN*
  - *NO_2*
  - *And other individual gases*

Using DS400 Docking Station for daily bump check and / or periodic calibration

- *Standalone operation: DS-400 does not require connection to an external computer*
- *Test results and other messages displayed on instrument LCD*

Using DS-400 Docking Station for daily bump check and / or periodic calibration

- *Using DS-400 allows instrument to record "Bump Test" as specific event in instrument's memory*
- *It is possible to set a "Bump Test Due" date in the instrument's memory*
- *Only way to reset next "Bump Test Due" date is by means of DS-400 Docking Station*

Using DS-400 Docking Station for daily bump check and / or periodic calibration

- *Make sure DS-400 attached to test gas and power*
- *Make sure the instrument is located in fresh air, turn on, and allow to warm up*
- *Note instrument readings, and perform fresh air zero if necessary*
- *Place instrument in DS-400*
- *Docking station controlled by instrument's control buttons:*
  - *Push "Test" for Bump Test*
  - *Push "Cal" for Auto Cal*
  - *Push "Cancel" to charge only*

How to do bump test

- *Make sure instrument turned on*
  - *Best if instrument allowed to warm-up at least 5 minutes before bump test*
- *Make sure Docking Station plugged in and connected to gas*
  - *Higher inlet is for fresh air*
  - *Lower inlet is for span gas*
- *Place instrument in Docking Station*
- *Instrument display will indicate status and results of test*

How to do bump test

- *After 10 second count-down; Docking Station automatically performs bump test*
- *Instrument screen shows a check mark besides each sensor as bump check completed*
- *If instrument is not removed from Docking Station; 5 minutes after test completed instrument automatically turns off and goes into charging mode*

DS400 Docking Station

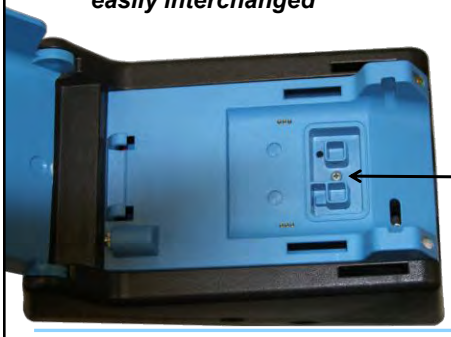
- *Bump-Test includes:*
  - *Visual alarm function*
  - *Audible alarm function*
  - *Time for activation to alarm 1*
  - *Time for activationto alarm 2*
  - *Time to t50*
- *Calibration Test Includes:*
  - *Fresh air zero adjustment*
  - *Span calibration adjustment*
- *All test results:*
  - *Stored to instrument memory*
  - *Stored to flash memory card in Docking Station*

What to do if instrument fails bump test

- *Red color warning screen and message indicates bump test failed*
- *This means instrument needs to be "Autocal" adjusted before further use*
- *Remove instrument from Dock, and press "Reset" (center) control button to clear alarm message*
- *Place instrument back in Dock*
- *Before end of count down press Autocal button*

DS-400 charging tray options

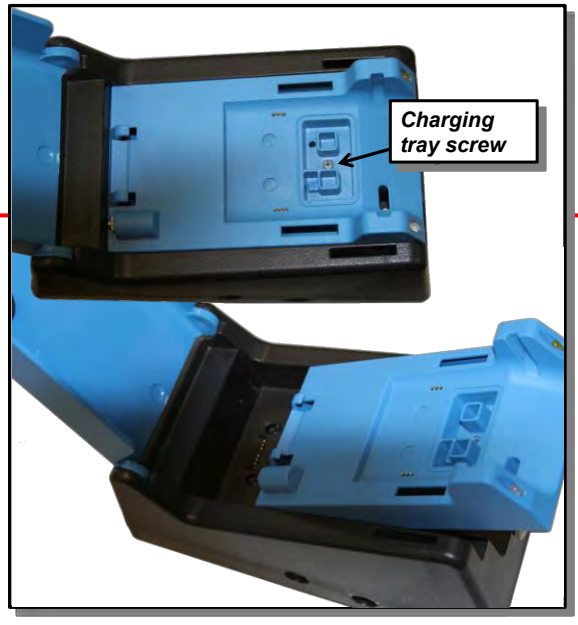
- *DS-400 Docking Stations can be equipped with a "single" or "double" charging tray for recharging the instrument and pump battery pack at the same time*
- *The trays are designed to be easily interchanged*



The charging tray is secured in the Docking Station housing by a single Phillips screw

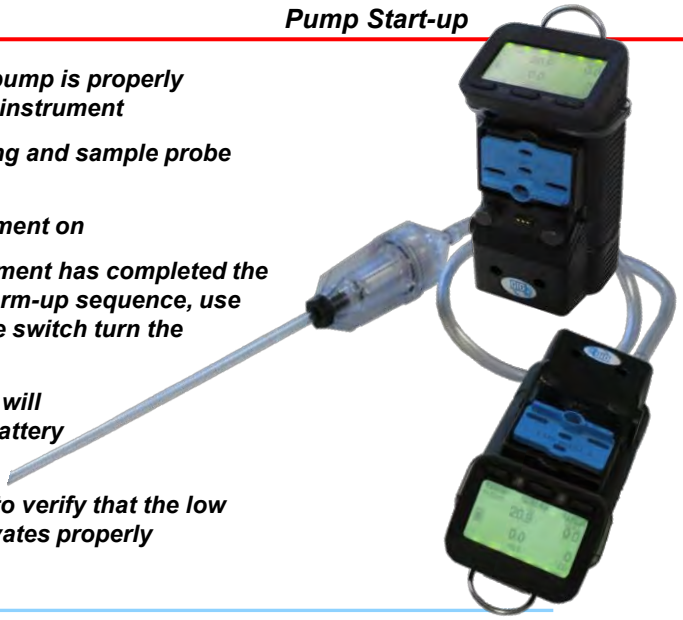
Removing or changing the DS-400 charging tray

- *Remove the charging tray screw;*
- *Lift the tray from the front and pull up and forward*



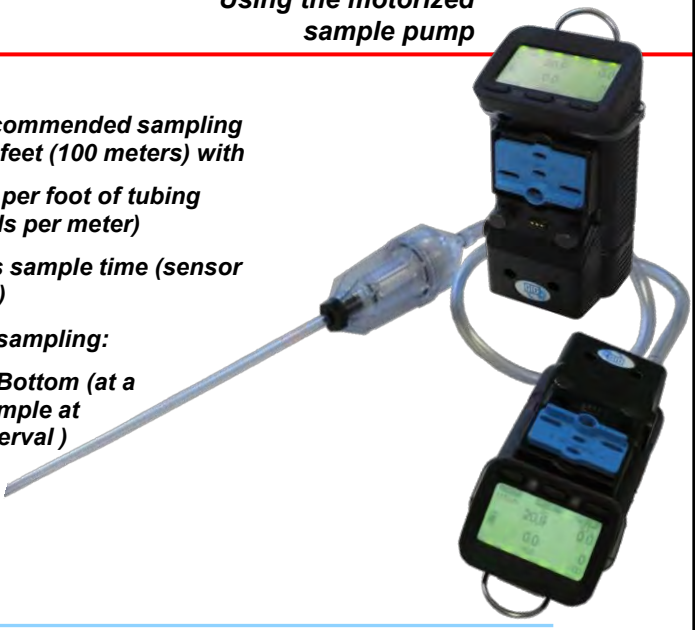
Pump Start-up

- *Make sure the pump is properly attached to the instrument*
- *Attach the tubing and sample probe assembly*
- *Turn the instrument on*
- *After the instrument has completed the self test and warm-up sequence, use the on / off slide switch turn the pump on*
- *The instrument will display pump battery status*
- *Block the inlet to verify that the low flow alarm activates properly*



Using the motorized sample pump

- *Sampling Rules*
  - *Maximum recommended sampling distance 300 feet (100 meters) with*
    - *1 second per foot of tubing (3 seconds per meter)*
    - *2 minutes sample time (sensor response)*
- *Confined Space sampling:*
  - *Top, Middle, Bottom (at a minimum, sample at every 4 ft. interval)*



Performing a gas test

- *Perform proper instrument start up*
- *Make sure instrument has been properly bump-tested before use*
- *Perform proper pump start up (if applicable)*
- *Make sure sample probe assembly is used whenever using the motorized sampling pump*
- *Make sure sample probe assembly is equipped with hydrophobic barrier and particulate filters – replace if discolored or dirty, or if the flow is being blocked*
- *Test all areas as required*
- *Fill in Gas Test Sheet*

Time required for proper testing

- *Wait until the sensor readings have completely stabilized!*
- *Remember that you may need up to 2-minutes – or even longer – for the sensors to finish stabilizing*
- *If tubing or a wand is used as well you have to add an additional 1-sec per foot of tubing for the gas to reach the sensors*
  - *So, if you were testing a vessel that was 10 feet deep and using 10 feet of tubing, how long would it take to sample and test the atmosphere in the bottom of the vessel?*
  - *2 minutes + (1 sec. x 10 feet) = 2.17 minutes*

The time it takes for the sensors to finish stabilizing after the gas begins to reach the sensors

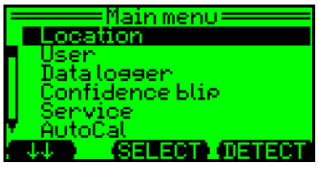
The time it takes for the pump to pull the sample through a 3.5 meter length of tubing

Time required for each test

WARNING: Advanced user options and setup choices should only be accessed or changed by authorized personnel

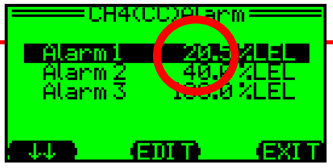
Advanced user options: Service Mode

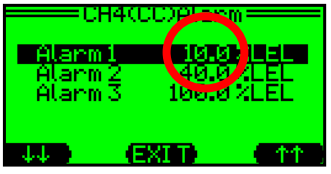
- ***From "Main menu" screen choose "Service"***
- ***The LCD will ask you for a security code***
- ***Enter "0 0 1 1"***
- ***The "Service menu" screen should appear with the following choices: "System" and "Sensors"***



Making a change and leaving "Service Mode"

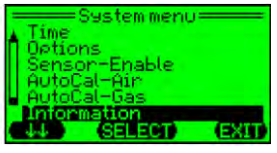
- *Use arrow keys to select (highlight) option or setting you intend to change*
- *Press "Edit", then use arrow keys to change setting*
- *Press "Exit" to return to normal operation (you may need to press "Exit" several times)*
- *You MUST press "Yes" to save the changes*





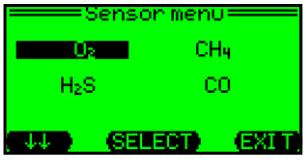
Advanced user options: Service Mode "System" menu

- *Use "System" choice to:*
  - *Set "Bump test" due date*
  - *Set "Calibration" due date*
  - *Set interval for "Inspection" due date*
  - *Set "Time"*
  - *Set system "Options" (language, vibrating alarm, alarm latch, SD card check, display zoom, auto-save setup changes)*
  - *"Sensor-Enable" to turn sensors off or on*
  - *"AutoCal – Air" specify which sensors adjusted during the "AutoCal – Air" procedure*
  - *"Autocal – Gas" specify which sensors adjusted during the "AutoCal – Gas" procedure*
  - *"Information" verify firmware version currently installed*



Advanced user options: Service Mode "Sensor" menu

- ***Use the "Sensors" choice to change settings for individual sensors***
- ***Each sensor has unique list of options and setting choices***

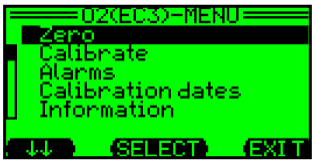


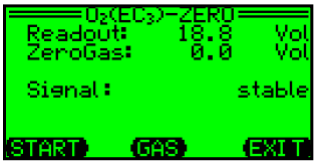
↓↓ - Move to next sensor
SELECT - Select sensor
Exit - Return to service Menu

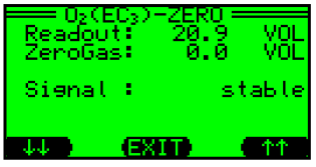
Advanced user options: Oxygen "Sensor" menu

- ***"Adjust Zero Point"***

WARNING: In the "Adjust Zero Point" procedure readings of the O_2 sensor are adjusted while the sensor is exposed to pure nitrogen (0.0% oxygen). Never attempt to "Adjust Zero Point" while the sensor is located in fresh air

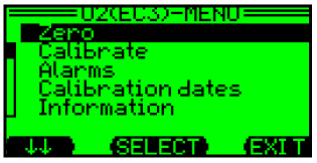


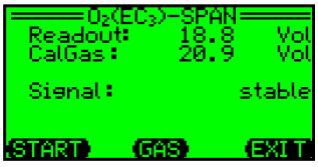


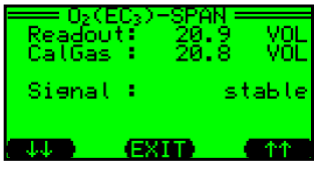


Advanced user options: Oxygen "Sensor" menu

- *"Calibration"*
  - *In this step oxygen sensor readings are span adjusted to match the concentration of oxygen in fresh air (20.9%)*
  - *This is the same procedure as the "AutoCal – air" adjustment normally used to adjust sensor readings to match the expected concentrations in fresh air*



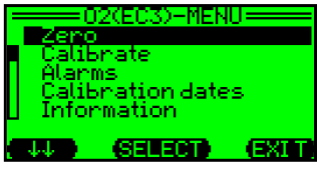




Advanced user options: Oxygen "Sensor" menu

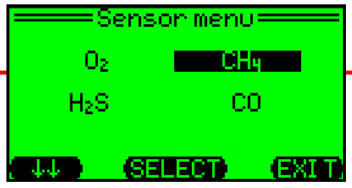
- *Oxygen sensors have three user adjustable alarm settings*
  - *Alarms 1 and 2 are normally "descending" alarms that are activated by the concentration falling below the alarm value*
  - *Alarm 3 is an "ascending" alarm that is activated by the concentration rising above the alarm value*
  - *Highlight the desired alarm, then press "Edit" to change the value*
  - *Press "Exit" to accept the new value and return to the O2 sensor menu*

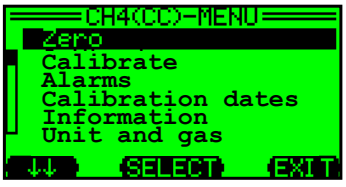
WARNING: Setting an alarm value to (– –) turns the alarm off. When the alarm is turned off the user will not be notified in the event of an alarm. This could result in injury or death.

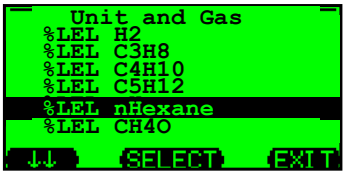


Advanced user options: LEL "Sensor" menu

- *LEL sensor menu choices:*
  - *Zero: Perform fresh air zero adjustment*
  - *Calibrate: Perform span calibration adjustment*
  - *Alarms: Change current alarm settings for LEL sensor*
  - *Calibration dates: Most recent three dates*
  - *Information: Display sensor ID information*
  - *Gas and unit: Choose correction factor for new gas from library*

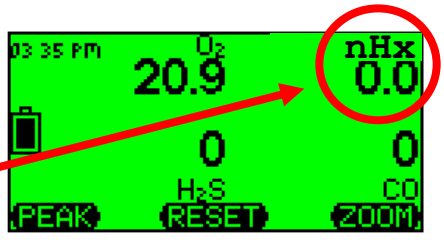


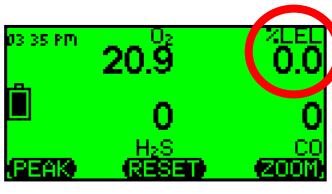




Selecting a new gas from the "Gas and Unit" library

- *LEL readings are displayed in measurement units for gas selected*
- *Name of gas selected will appear in the sensor menu LEL position*
- *In normal operation screen will show name of new gas selected in place of "% LEL"*





CC LEL sensor "Gas and Unit" library choices

- *The following CC LEL sensor "gas and unit" choices are available as setup choices in the on-board library:*

CC LEL Gas List	Common Name
CH4	Methane
H2	Hydrogen
CH4O	Methanol
C3H8	Propane
C2H6O	Dimethylether
Acetone	Acetone
C3H8O	Isopropyl Alcohol
C3H6O2	Methyl Acetate
C4H10	Butane
EtActat	Ethyl Acetate
n-Butanol	n-Butyl alcohol
C5H12	Pentane
MEK	Methyl Ethyl Ketone
MIBK	Methyl Isobutyl Ketone
n-Hexane	n-Hexane

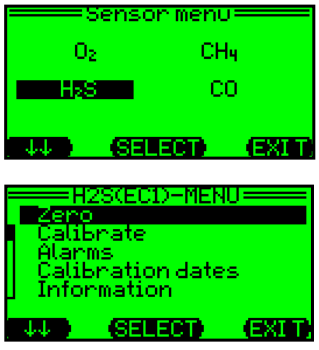
Additional catalytic LEL sensor response factors

- *Listed responses are for guidance only*
- *Relative response ratios may differ from sensor to sensor, and may shift over the life of the sensor*
- *Cumulative exposure to sensor poisons and / or inhibitors may also affect the relative response ratios*
- *The relative response values have been rounded to the nearest 5%*

Gas	Relative response (compared to CH4)	Correction factor
Acetone	0.70	1.43
Acetylene	0.900	1.11
Ammonia	1.40	0.71
1, 3-Butadiene	0.60	1.67
n-Butane	0.65	1.54
Carbon monoxide	1.20	0.83
Cyclohexane	0.50	2.00
Ethyl acetate	0.55	1.82
Ethyl alcohol	0.85	1.18
Ethylene	0.90	1.11
Gasoline (unleaded)	0.60	1.67
Gasoline (leaded)	0.60	1.67
n-Heptane	0.45	2.22
n-Hexane	0.55	1.82
Hydrogen	1.10	0.91
Isobutylene	0.80	1.25
Isopropyl alcohol	0.65	1.54
Methane	1.00	1.00
Methyl alcohol	0.85	1.18
Methylethylketone	0.55	1.82
n-Octane	0.35	2.86
n-Pentane	0.55	1.82
Propane	0.65	1.54
Propylene	0.87	1.15
Toluene	0.40	2.50

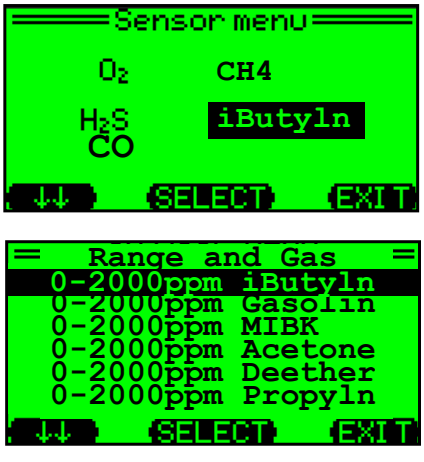
Advanced user options: Toxic "Sensor" menus

- *Toxic sensor menu choices include:*
  - *Zero: Perform fresh air zero adjustment*
  - *Calibrate: Perform span calibration adjustment*
  - *Alarms: Change current alarm settings for LEL sensor*
  - *Calibration dates: Most recent three dates*
  - *Information: Display sensor ID information*



PID sensor menu

- *PID sensor choices include "Range and Gas"*
- *Use to choose correction factor for new gas from PID library*
- *PID readings displayed in measurement units of gas selected*
- *Name of gas selected will appear in the sensor menu PID position*
- *In normal operation screen will show name of new gas*

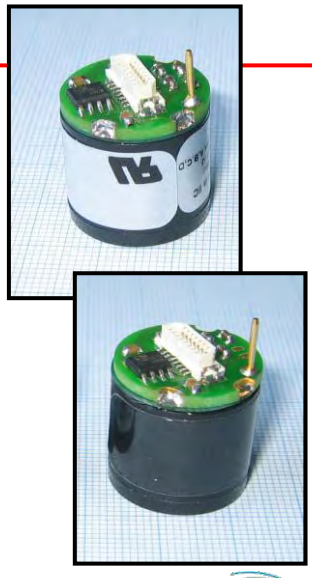


PID sensor "Gas and Unit" library choices

PID Gas List Abbreviations	Common Name	Range with 0 – 2000 ppm full range PID (ISO)	Range with 0 – 500 ppm full range PID (ISO)
iButyln	Isobutylene	0 – 2000	0 – 500
VOC	Generic VOC with user assigned CF	0 – 2000	0 – 500
Gasolin	Gasoline	0 – 2000	0 – 500
MIBK	Methyl-iso-butyl-ketone	0 – 2000	0 – 500
Acetone	Acetone	0 – 2000	0 – 500
Deether	Diethylether	0 – 2000	0 – 500
Propyln	Propylene	0 – 2000	0 – 500
MEK	Methyl-ethyl-ketone	0 – 1500	0 – 375
Diesel	Diesel	0 – 1500	0 – 375
TrClEyn	Trichloroethylene	0 – 1000	0 – 250
Benzene	Benzene	0 – 1000	0 – 250
Toluene	Toluene	0 – 1000	0 – 250
Xylene	Xylene	0 – 1000	0 – 250
Styrene	Styrene	0 – 800	0 – 200
Jetfuel	Jet fuel (JP-8)	0 – 800	0 – 200
nButnol	n-Butyl-alcohol	0 – 6000	0 – 1500
EtActat	Ethyl acetate	0 – 6000	0 – 1500
nHexane	n-Hexane	0 – 6000	0 – 1500
NH3	Ammonia	0 – 6000	0 – 1500
cHexane	Cyclo hexane	0 – 3000	0 – 750
VyChlrd	Vinyl chloride (VCM)	0 – 3000	0 – 750
MeBromd	Methyl bromide	0 – 3000	0 – 750
nNonane	n-Nonane	0 – 3000	0 – 750
Octane	Octane	0 – 3000	0 – 750
Heptane	Heptane	0 - 3000	0 – 750

PID range and resolution

- *Two versions of the PID sensor available for G460:*
  - *"Standard" PID provides 0.5 ppm resolution over 0 – 2000 ppm (isobutylene scale)*
  - *"High Resolution" PID provides 0.1 ppm resolution over 0 – 500 ppm (isobutylene scale)*
- *"VOC" choice allows the user to specify custom correction factor for a gas not included in the standard on-board library*
- *The full range for the gas selected depends on the relative response of the sensor to the target gas compared to isobutylene*
  - *For instance, when "NH3" (ammonia) is selected, because of the lower relative response to ammonia compared to isobutylene, the full range is expanded from 0 – 2000 (iso scale) to 0 – 6000 ppm (NH3 scale)*

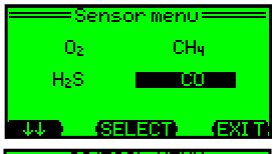


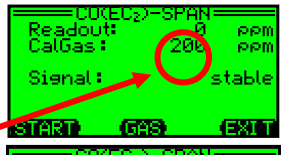
Advanced user options: Viewing or changing span gas values

- *G450 / G460 instruments automatically adjust sensor readings during the AutoCal® process*
  - *Fresh "Air" AutoCal® adjusts sensor readings to match those expected in uncontaminated air that contains 20.9% O_2*
  - *"Gas" AutoCal® adjusts sensor readings to match the concentrations in the calibration gas used for this procedure*
  - *The factory default "span" gas values used by the instrument to adjust sensor readings are:*
    - *LEL Sensor: 50% LEL*
    - *CO Sensor: 200 ppm*
    - *H_2S Sensor: 20 ppm*

Advanced user options: Viewing or changing span gas values

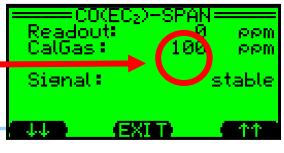
- *In order to use gas with a different concentration to calibrate the instrument, you will need to change the span "Gas" value for that sensor*
- *From the "Sensor Menu" choose the sensor with the span gas values you want to view or change, then choose "Calibrate", then "Gas"*
- *Use the arrow keys to adjust the gas value, then "Exit"*





Old value

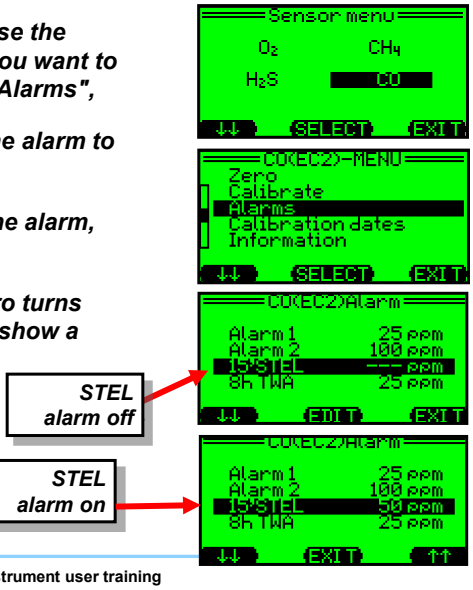
New value



Advanced user options: Viewing or changing alarms

- *From the "Sensor Menu" choose the sensor with the alarm values you want to view or change, then choose "Alarms",*
- *Use the arrow keys to select the alarm to adjust, then "Edit"*
- *Use the arrow keys to adjust the alarm, the "Exit" when finished*

NOTE: Setting the value to zero turns the alarm off. The display will show a dashed line.



STEL alarm off

STEL alarm on

Questions?