Recent changes in the rules for confined space entry

What's in, what's out, what's new, and what's needed

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GfG Instrumentation

World-wide manufacturer of gas detection solutions

www.Goodforgas.com website

Technical support and downloads

- www.goodforgas.com
  - *Application Notes, Technical Notes and Presentations:*

    http://goodforgas.com/support/#appnotes

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History of OSHA Confined Space Entry Requirements

- ***In 1993 OSHA enacted 29 CFR 1910.146 "Permit-Required Confined Spaces"***
- ***Provisions applied only to general industry work***
- ***Original intent was to extend 1910.146 to include construction***
- ***However, it was quickly recognized that 1910.146 did not fully address issues unique to the construction industry, such as:***
  - ***Higher employee turnover rates***
  - ***Worksites that change frequently***
  - ***Multi-employer business model***

OSHA 29 CFR 1910.146

- ***1910.146 Permit Required Confined Spaces is a "horizontal standard"***
  - ***Includes requirements for practices and procedures to protect employees in general industry***
  - ***If an employee is working in an industry where a vertical or industry-specific standard applies, then the entry is subject to the vertical standard***
  - ***If a vertical standard not applicable, the general industry standard prevails***
- ***1910.146 does not apply to industries with their own vertical standards:***
  - ***Agriculture***
  - ***Construction***
  - ***Shipyard employment***

29 CFR 1926 Subpart AA: Confined Spaces in Construction

- ***Even though the construction activity might be taking place in a confined space, 1910.146 does not apply***
- ***Until recently, this left a gap construction related CS procedures***
- ***As of 2015, Construction finally has its own standard: 29 CFR 1926 Subpart AA "Confined Spaces in Construction"***

29 CFR 1926 Subpart AA: Confined Spaces in Construction

- ***The Construction CS rule is similar in content and organization to the general industry confined spaces standard, but incorporates additional provisions that address construction-specific hazards***

- ***Includes a permit program designed to protect employees from atmospheric and physical hazards associated with work in construction confined spaces***

Characteristics of Confined Spaces

- *Large enough for worker to enter*
- *Are not designed for continuous worker occupancy*
- *Limited openings for entry and exit*

Meeting basic CS criteria

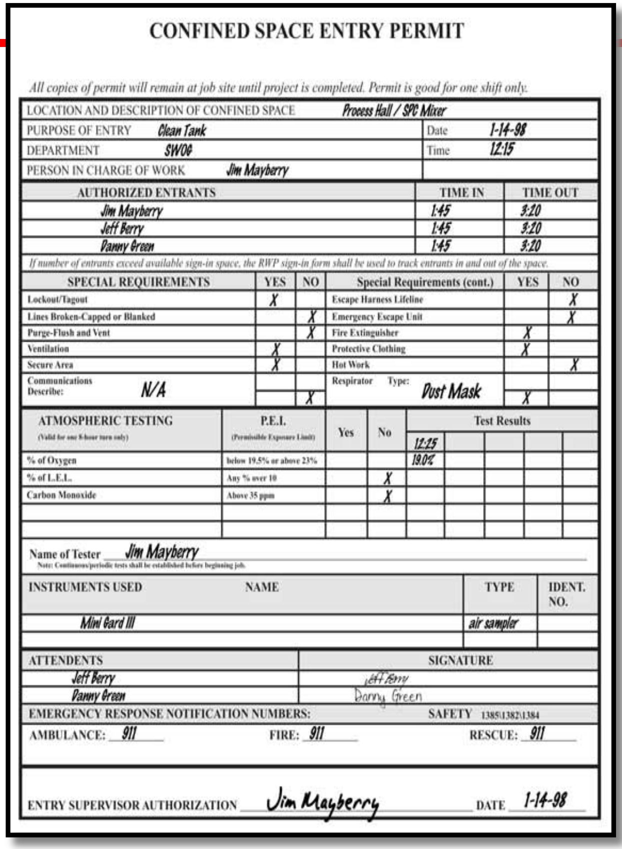
- ***Limited means of entry and exit***
- ***Not designed for continuous occupancy***

Permit Required Confined Spaces

- *One or more of the following:*
  - ***Hazardous atmosphere (known or potential)***
  - ***Material with the potential for engulfment***
  - ***Inwardly sloping walls or dangerously sloping floors***

    or

  - ***Contains any other serious safety hazard***



CONFINED SPACE ENTRY PERMIT

All copies of permit will remain at job site until project is completed. Permit is good for one shift only.

LOCATION AND DESCRIPTION OF CONFINED SPACE Process Hall / SPC Mixer	
PURPOSE OF ENTRY Clean Tank	Date 1-14-98
DEPARTMENT SWOG	Time 12:15
PERSON IN CHARGE OF WORK Jim Mayberry	

AUTHORIZED ENTRANTS	TIME IN	TIME OUT
Jim Mayberry	1:45	3:20
Jeff Berry	1:45	3:20
Danny Green	1:45	3:20

If number of entrants exceed available sign-in space, the RWP sign-in form shall be used to track entrants in and out of the space.

SPECIAL REQUIREMENTS	YES	NO	Special Requirements (cont.)	YES	NO
Lockout/Tagout	X		Escape Harness Lifeline		X
Lines Broken-Capped or Blanked		X	Emergency Escape Unit		X
Purge-Flush and Vent		X	Fire Extinguisher	X	
Ventilation	X		Protective Clothing	X	
Secure Area	X		Hot Work		X
Communications Describe: N/A		X	Respirator Type: Dust Mask	X	

ATMOSPHERIC TESTING (Valid for one 8-hour turn only)	P.E.L. (Permissible Exposure Limit)	Yes	No	Test Results 12:25				
% of Oxygen	below 19.5% or above 23%			19.0%				
% of L.E.L.	Any % over 10		X					
Carbon Monoxide	Above 35 ppm		X					

Name of Tester Jim Mayberry

Note: Continuous/periodic tests shall be established before beginning job.

INSTRUMENTS USED NAME	TYPE	IDENT. NO.
Mini Gard III	air sampler	

ATTENDENTS	SIGNATURE
Jeff Berry	Jeff Berry
Danny Green	Danny Green

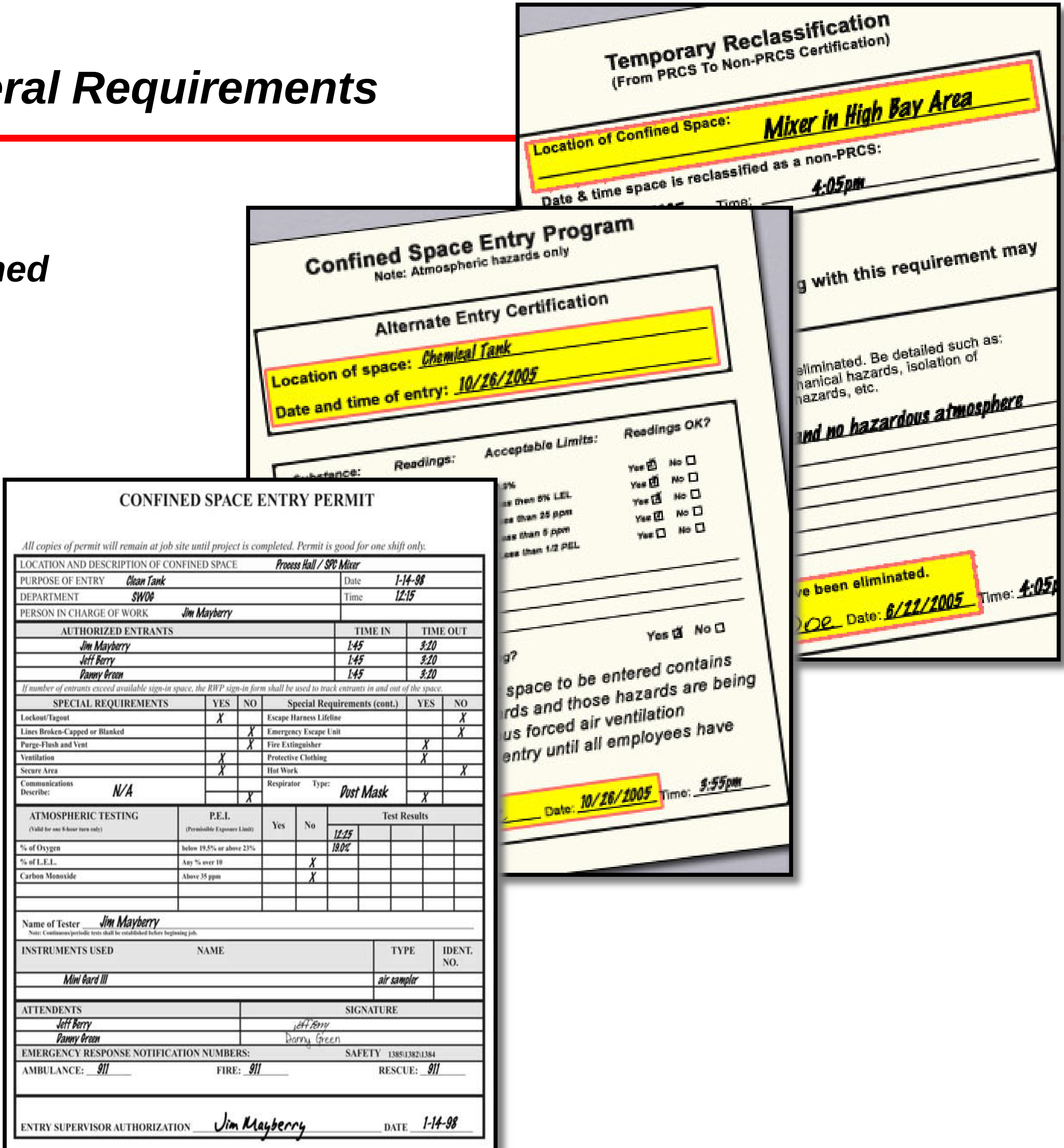
EMERGENCY RESPONSE NOTIFICATION NUMBERS: SAFETY 1385\1382\1384

AMBULANCE: 911 FIRE: 911 RESCUE: 911

ENTRY SUPERVISOR AUTHORIZATION Jim Mayberry DATE 1-14-98

General Requirements

- Options for entry into Permit Required Confined Space (PRCS)
  - Reclassification
  - Alternate entry procedures
  - Permit program



Under 1910.146, <u>after construction</u>, these are normally non-permit confined spaces

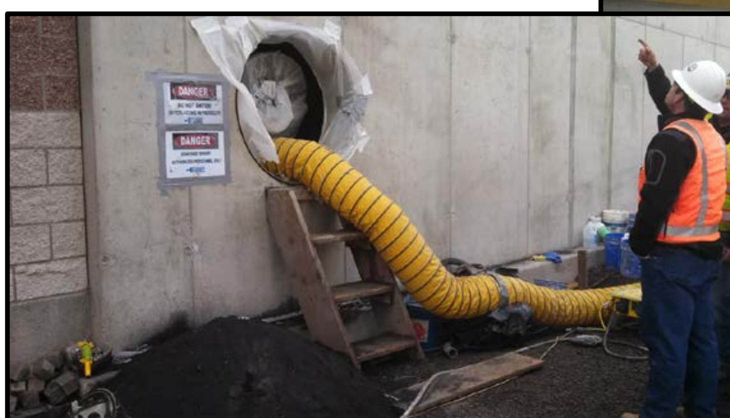
- ***Large enough for worker to enter***
- ***Are not designed for continuous worker occupancy***
- ***Limited openings for entry and exit***
- ***However, there are no other serious safety hazards***

Under 1926 Subpart AA, <u>during construction,</u> these can easily be permit confined spaces!

- ***It depends on what is being done at that moment in the construction process***
- ***For example:***
  - ***Sealant is being applied in the crawl space, the atmosphere may be hazardous due to toxic vapors***
  - ***O_2 catalyzed sealants and freshly poured concrete absorb oxygen while curing, which can lead to O_2 deficiency***

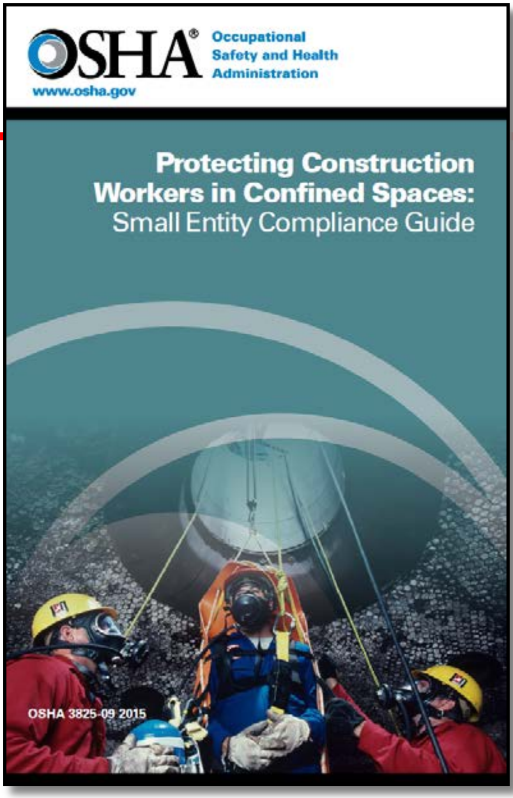
Types of confined spaces covered by 1926 Subpart AA

- ***29 CFR 1926 includes a lengthy list of confined spaces that are covered by the new rule***
- ***The list includes many types of spaces that are not usually deemed to be permit confined spaces under the general industry rule (29 CFR 1946)***



Typical construction confined spaces

- *Boilers*
- *Manholes (sewer, storm drain, electrical, communication, utility, etc.)*
- *Precast concrete manhole units*
- *Tanks (fuel, chemical, water, other liquid, solid or gas)*
- *Incinerators*
- *Concrete pier columns*
- *Sewers and storm drains*
- *Transformer vaults*
- *Heating, ventilation, and air-conditioning (HVAC) ducts*
- *Cesspools*
- *Mixers/reactors*
- *Bag houses*
- *Turbines*
- *Silos*
- *Chillers*

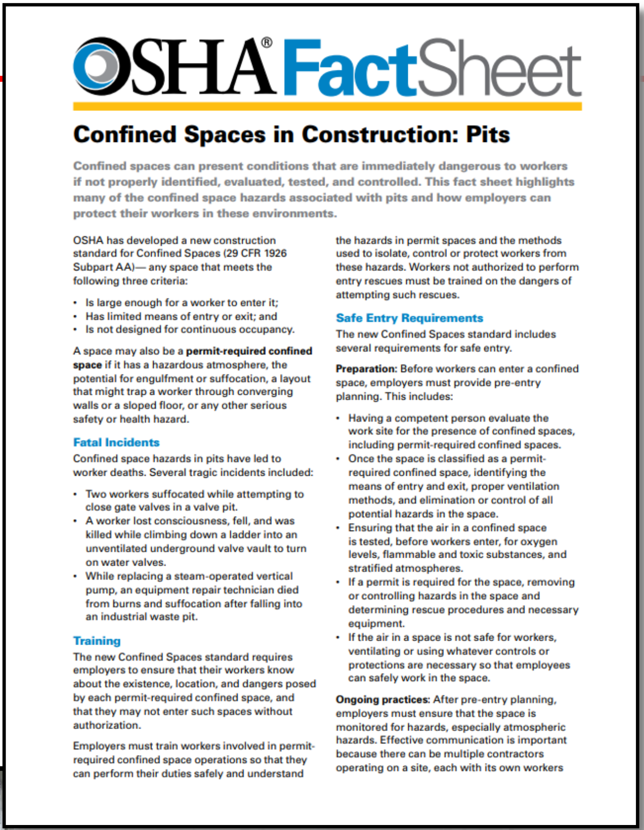


https://www.osha.gov/Publications/OSHA3825.pdf

Some confined spaces are open topped

- *Open-topped water tanks*
- *Digesters and lift stations*
- *Bins*
- *Degreasers*
- *Pits (elevator, escalator, pump, valve, etc.)*

https://www.osha.gov/Publications/OSHA3788.pdf



OSHA® FactSheet

Confined Spaces in Construction: Pits

Confined spaces can present conditions that are immediately dangerous to workers if not properly identified, evaluated, tested, and controlled. This fact sheet highlights many of the confined space hazards associated with pits and how employers can protect their workers in these environments.

OSHA has developed a new construction standard for Confined Spaces (29 CFR 1926 Subpart AA)— any space that meets the following three criteria:

- Is large enough for a worker to enter it;
- Has limited means of entry or exit; and
- Is not designed for continuous occupancy.

A space may also be a **permit-required confined space** if it has a hazardous atmosphere, the potential for engulfment or suffocation, a layout that might trap a worker through converging walls or a sloped floor, or any other serious safety or health hazard.

Fatal Incidents

Confined space hazards in pits have led to worker deaths. Several tragic incidents included:

- Two workers suffocated while attempting to close gate valves in a valve pit.
- A worker lost consciousness, fell, and was killed while climbing down a ladder into an unventilated underground valve vault to turn on water valves.
- While replacing a steam-operated vertical pump, an equipment repair technician died from burns and suffocation after falling into an industrial waste pit.

Training

The new Confined Spaces standard requires employers to ensure that their workers know about the existence, location, and dangers posed by each permit-required confined space, and that they may not enter such spaces without authorization.

Employers must train workers involved in permit-required confined space operations so that they can perform their duties safely and understand the hazards in permit spaces and the methods used to isolate, control or protect workers from these hazards. Workers not authorized to perform entry rescues must be trained on the dangers of attempting such rescues.

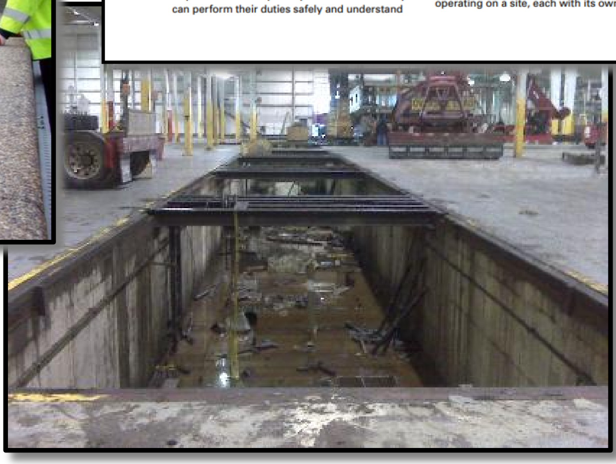
Safe Entry Requirements

The new Confined Spaces standard includes several requirements for safe entry.

Preparation: Before workers can enter a confined space, employers must provide pre-entry planning. This includes:

- Having a competent person evaluate the work site for the presence of confined spaces, including permit-required confined spaces.
- Once the space is classified as a permit-required confined space, identifying the means of entry and exit, proper ventilation methods, and elimination or control of all potential hazards in the space.
- Ensuring that the air in a confined space is tested, before workers enter, for oxygen levels, flammable and toxic substances, and stratified atmospheres.
- If a permit is required for the space, removing or controlling hazards in the space and determining rescue procedures and necessary equipment.
- If the air in a space is not safe for workers, ventilating or using whatever controls or protections are necessary so that employees can safely work in the space.

Ongoing practices: After pre-entry planning, employers must ensure that the space is monitored for hazards, especially atmospheric hazards. Effective communication is important because there can be multiple contractors operating on a site, each with its own workers



Confined Spaces in Construction: Crawl Spaces and Attics

- ***Even if the space is not a PRCS <u>after</u> construction, it may represent a dangerous permit space at certain stages during construction***
- ***Confined space hazards in crawl spaces and attics have led to worker deaths:***
  - ***Two workers died while applying primer to floor joists in a crawl space. They were burned when an incandescent work lamp ignited vapors from the primer.***
  - ***A flash fire killed a worker who was spraying foam insulation in an enclosed attic. The fire was caused by poor ventilation.***

General Requirements

- ***Employers Must:***
  - ***Identify Confined Space hazard areas***
  - ***Inform employees by posting signs where feasible***
  - ***Prevent entry by unauthorized persons***

General Requirements

- ***Employers must ensure the required equipment is available:***
  - ***Testing and monitoring***
  - ***Ventilation***
  - ***Communications***
  - ***Lighting***
  - ***Barriers***
  - ***Other personal protective equipment***
  - ***Any required rescue and emergency equipment***

General Requirements

- ***Employers Must:***
  - ***Establish procedures and practices to allow safe entry (Permit system)***
  - ***Train employees / verify workers are competent***
  - ***Ensure required equipment is available and used***
  - ***Control hazards where possible through engineering or work practices***

General Requirements

- *Employers Must:*
  - *Protect entrants from external hazards*
  - *Enforce established procedures*
  - *Ensure procedures and equipment necessary for rescue*
    - *Calling 911 after the accident occurs is not a plan!*

    https://www.osha.gov/Publications/OSHA3849.pdf

OSHA® FactSheet

Is 911 your Confined Space Rescue Plan?

Permit-required confined spaces can present conditions that are immediately dangerous to workers' lives or health if not properly identified, evaluated, tested and controlled.

OSHA has developed a standard for Confined Spaces in Construction (29 CFR 1926 Subpart AA) for any space that meets all of the following criteria:

- Is large enough for a worker to enter;
- Has limited means of entry or exit; and
- Is not designed for continuous occupancy.

One provision of the standard requires employers to develop and implement procedures for summoning rescue or emergency services in permit-required confined spaces. An employer who relies on local emergency services for assistance is required to meet the requirements of §1926.1211 — *Rescue and emergency services.*

OSHA recognizes that not all rescue services or emergency responders are trained and equipped to conduct confined space rescues. When employers identify an off-site rescue service, it is critical that the rescuers can protect their employees. The emergency services should be familiar with the exact site location, types of permit-required confined spaces and the necessary rescue equipment.

For Employers

Calling emergency responders to provide rescue services can be a suitable way of providing for rescues in a permit-required confined space. Pre-planning will ensure that the emergency service is capable, available and prepared.

Prior to the start of the rescue work operation, employers must evaluate prospective emergency responders and select one that has:

- Adequate equipment for rescues, such as: atmospheric monitors, fall protection, extraction equipment, and self-contained breathing apparatus (SCBA) for the particular permit-required confined spaces.

Photo: Oregon/OSHA

Emergency service workers perform a practice rescue inside a manhole.

- The ability to respond and conduct a rescue in a timely manner based on the site conditions and is capable of conducting a rescue if faced with potential hazards specific to the space. Such hazards may include:
  - Atmospheric hazards (e.g., flammable vapors, low oxygen)
  - Electrocution (e.g., unprotected, energized wires)
  - Flooding or engulfment potential
  - Poor lighting
  - Fall hazards
  - Chemical hazards
- Agreed to notify the employer in the event that the rescue team becomes unavailable.

Employers must also:

- Inform the emergency responders of potential hazards when they are called to perform a rescue at the worksite; and

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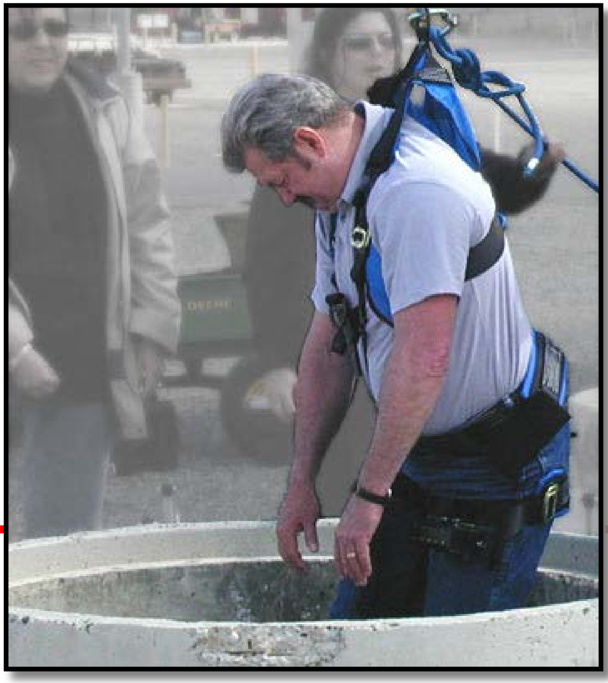


Rescue

- ***Self rescue: Entry procedures should aim at getting workers out under their own power BEFORE conditions become life threatening***
- ***Non-entry rescue: Second best approach is to use procedures that allow rescue without having to enter the space***
- ***Rescuer entry: Least desirable, highest risk, most equipment and personnel intensive approach***

1926 Subpart AA: Increased emphasis on training

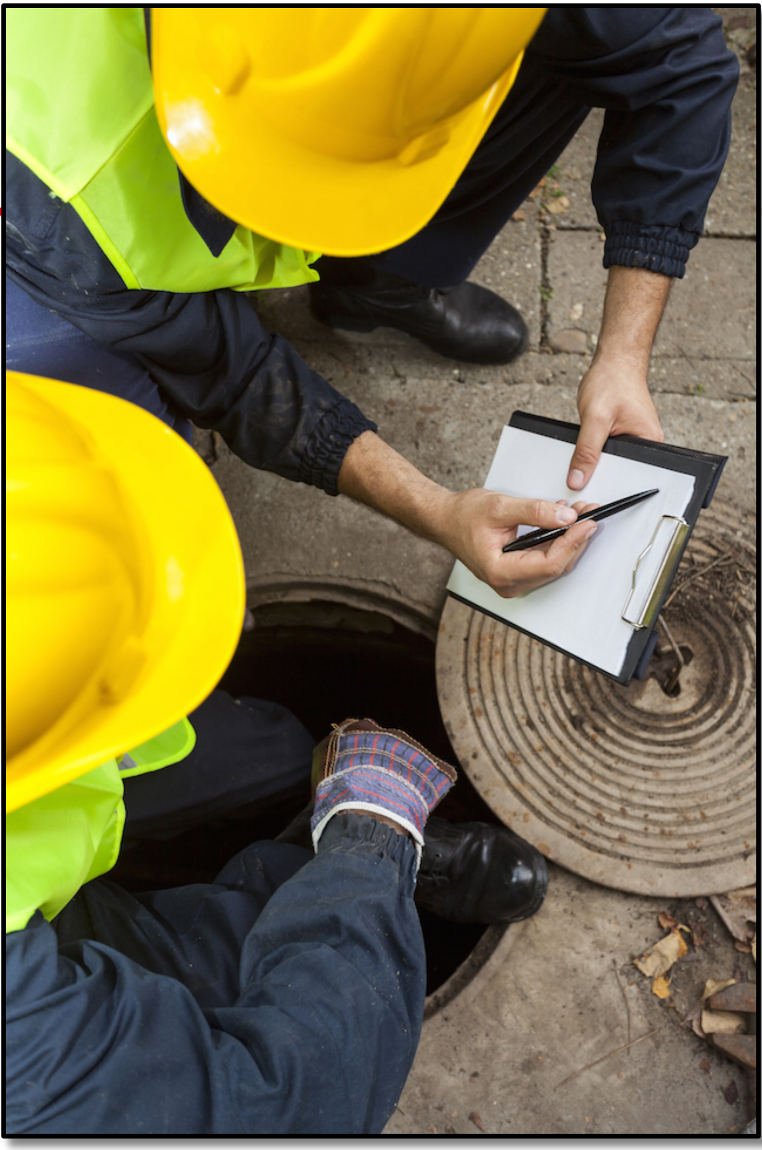
- ***Dangers associated with construction confined spaces can change from day-to-day because of the work being performed***
- ***Even more important that workers are trained to recognize potential dangers!***
- ***Employer <u>must</u> ensure employees possess knowledge and necessary skills and are <u>competent</u> for the safe performance of their assigned duties***
  - ***Understand the hazards and the methods used to isolate, control and protect employees***
  - ***Understand the dangers of attempting rescues <u>unless</u> trained, equipped and <u>authorized</u> to do so!***

1926 Subpart AA: Increased emphasis on communication

- ***Workers and contractors at construction site can change from day to day***

- ***The <u>Entry Employer</u> must ensure that all <u>Entry Supervisors</u>, <u>Authorized Entrants</u> and <u>Attendants</u> are properly trained, and that they properly follow the requirements of the Employer's confined space entry program***

- ***Whenever responsibility for a PRCS is transferred the <u>Entry Supervisor</u> determines that entry operations remain consistent with terms of the entry permit and that acceptable entry conditions are maintained***



Realtime wireless communication

Optional radio frequency (RF) transmitter

Realtime wireless communication of readings and alarms

Sophisticated wireless “Man down” alarm provides immediate information of movement and horizontal attitude of worker

Powerful transmitter provides over 1000m direct line of sight communication

License free ISM band operation

Digital repeater transmitters allow extended transmission distance

1926.1203(e)(2): Requires calibrated direct reading instrument

- ***Perform "bump test" or "calibration check" on all sensors before each day's use***
- ***Calibrate and maintain instrument per manufacturer requirements***
- ***Maintain records that prove these requirements are being met***
- ***GfG Application Note 1007: Calibration and Bump Test Requirements***

http://goodforgas.com/wp-content/uploads/2014/09/AP1007_calibration_requirements_for_direct_reading_portable_gas_monitors_8_AUG_14.pdf

AP 1007: Calibration and Bump Test Requirements for Direct Reading Portable Gas Monitors

Manufacturers and regulatory agencies agree the safest and most conservative approach is to perform a functional test by exposing your gas detector to test gas before each day's use.

Oxygen deficiencies, explosive atmospheres, and exposure to toxic gases and vapors injure hundreds of workers every year. The atmospheric conditions that lead to these accidents and fatalities are usually invisible to the workers who are involved. The only way to ensure atmospheric conditions are safe is to use an atmospheric monitor. The only way to know whether an instrument is capable of proper performance is to expose it to test gas. Exposing the instrument to known concentration test gas verifies that gas is properly able to reach and be detected by the sensors. It verifies the proper performance of the instrument's alarms, and (if the instrument is equipped with a real-time display), that the readings are accurate. Failure to periodically test and document the performance of your atmospheric monitors can leave you open to regulatory citations or fines, as well as increased liability exposure in the event that a worker is injured in an accident.

There has never been a consensus among manufacturers regarding how frequently direct reading portable gas detectors need to be calibrated. However, manufacturers do agree that the safest and most conservative approach is to verify the performance of the instrument by exposing it to test gas before each day's use. Performing a functional "bump test" is very simple and takes only a few seconds to accomplish. It is not necessary to make a calibration adjustment unless the readings are found to be inaccurate. The regulatory standards that govern confined space entry and other activities that include the use of direct reading instruments are in agreement with this approach.

However, the definition of "bump test" has always been a little slippery. Some manufacturers differentiate between a "bump test" that provides a qualitative evaluation of the instrument's ability to detect gas and a "calibration check" that verifies that the response of the sensor(s) when exposed to known concentration test gas are within the manufacturer's requirements for accuracy. All manufacturers agree that instruments that fail either a "bump test" or "calibration check" should be put through a "full calibration" before further use.

ISEA Statement on Validation of Operation for Direct Reading Portable Gas Monitors

The International Safety Equipment Association (ISEA) is the leading international organization of manufacturers of safety equipment, including environmental monitoring instruments. The ISEA is dedicated to protecting the health and safety of workers through the development of workplace standards and the education of users on safe work practices and exposure prevention. In 2010 the ISEA updated their protocol for, *"Validation Procedures of Operation For Direct Reading Portable Gas Monitors"* to clarify the Association's recommendations for the procedures used to verify proper operation, and the accuracy of the readings.

The protocol was designed to reemphasize to OSHA and other standards writing bodies the importance of verifying the calibration of instruments used to monitor the atmosphere in potentially hazardous locations, to clarify the differences

Figure 1: Performing a functional "bump test" by exposing the instrument to test gas takes only a few moments perform.

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AP1007_8_AUG_14

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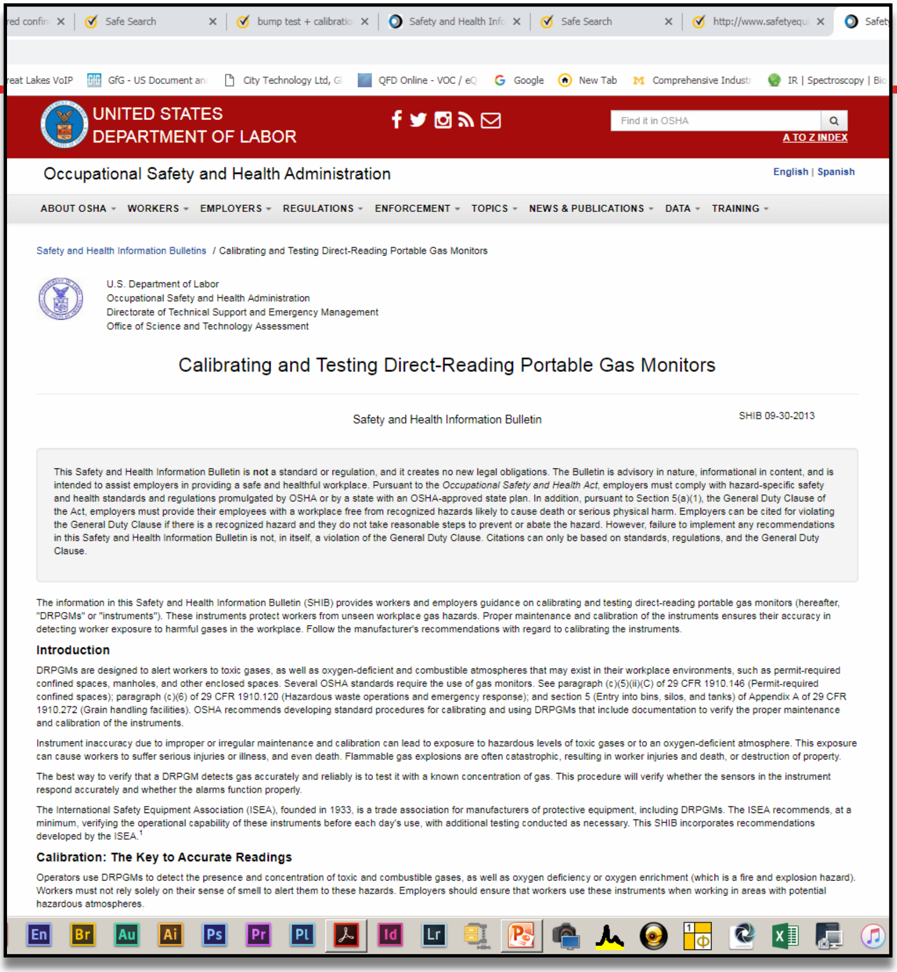
Bump test and calibration definitions and requirements

- *OSHA definition of "bump test"*
  - *Exposure to test gas to activate alarms for all sensors*
  - *No adjustment of sensors*
  - *Required "Before each day's use"*
- *OSHA definition of "calibration check"*
  - *Instrument exposed to known concentration calibration gas*
  - *Sensor readings must stabilize within tolerance of manufacturer specification*
  - *No adjustment of sensors*
- *Calibration*
  - *Two steps: adjustment of sensors to fresh air values, then adjustment of sensors using calibration gas*
  - *Calibrate whenever instrument fails daily check or as specified by manufacturer*



UNITED STATES DEPARTMENT OF LABOR

Occupational Safety and Health Administration

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Safety and Health Information Bulletins / Calibrating and Testing Direct-Reading Portable Gas Monitors

U.S. Department of Labor
Occupational Safety and Health Administration
Directorate of Technical Support and Emergency Management
Office of Science and Technology Assessment

Calibrating and Testing Direct-Reading Portable Gas Monitors

Safety and Health Information Bulletin — SHIB 09-30-2013

This Safety and Health Information Bulletin is **not** a standard or regulation, and it creates no new legal obligations. The Bulletin is advisory in nature, informational in content, and is intended to assist employers in providing a safe and healthful workplace. Pursuant to the *Occupational Safety and Health Act*, employers must comply with hazard-specific safety and health standards and regulations promulgated by OSHA or by a state with an OSHA-approved state plan. In addition, pursuant to Section 5(a)(1), the General Duty Clause of the Act, employers must provide their employees with a workplace free from recognized hazards likely to cause death or serious physical harm. Employers can be cited for violating the General Duty Clause if there is a recognized hazard and they do not take reasonable steps to prevent or abate the hazard. However, failure to implement any recommendations in this Safety and Health Information Bulletin is not, in itself, a violation of the General Duty Clause. Citations can only be based on standards, regulations, and the General Duty Clause.

The information in this Safety and Health Information Bulletin (SHIB) provides workers and employers guidance on calibrating and testing direct-reading portable gas monitors (hereafter, "DRPGMs" or "instruments"). These instruments protect workers from unseen workplace gas hazards. Proper maintenance and calibration of the instruments ensures their accuracy in detecting worker exposure to harmful gases in the workplace. Follow the manufacturer's recommendations with regard to calibrating the instruments.

Introduction

DRPGMs are designed to alert workers to toxic gases, as well as oxygen-deficient and combustible atmospheres that may exist in their workplace environments, such as permit-required confined spaces, manholes, and other enclosed spaces. Several OSHA standards require the use of gas monitors. See paragraph (c)(5)(ii)(C) of 29 CFR 1910.146 (Permit-required confined spaces); paragraph (c)(6) of 29 CFR 1910.120 (Hazardous waste operations and emergency response); and section 5 (Entry into bins, silos, and tanks) of Appendix A of 29 CFR 1910.272 (Grain handling facilities). OSHA recommends developing standard procedures for calibrating and using DRPGMs that include documentation to verify the proper maintenance and calibration of the instruments.

Instrument inaccuracy due to improper or irregular maintenance and calibration can lead to exposure to hazardous levels of toxic gases or to an oxygen-deficient atmosphere. This exposure can cause workers to suffer serious injuries or illness, and even death. Flammable gas explosions are often catastrophic, resulting in worker injuries and death, or destruction of property.

The best way to verify that a DRPGM detects gas accurately and reliably is to test it with a known concentration of gas. This procedure will verify whether the sensors in the instrument respond accurately and whether the alarms function properly.

The International Safety Equipment Association (ISEA), founded in 1933, is a trade association for manufacturers of protective equipment, including DRPGMs. The ISEA recommends, at a minimum, verifying the operational capability of these instruments before each day's use, with additional testing conducted as necessary. This SHIB incorporates recommendations developed by the ISEA.[1]

Calibration: The Key to Accurate Readings

Operators use DRPGMs to detect the presence and concentration of toxic and combustible gases, as well as oxygen deficiency or oxygen enrichment (which is a fire and explosion hazard). Workers must not rely solely on their sense of smell to alert them to these hazards. Employers should ensure that workers use these instruments when working in areas with potential hazardous atmospheres.

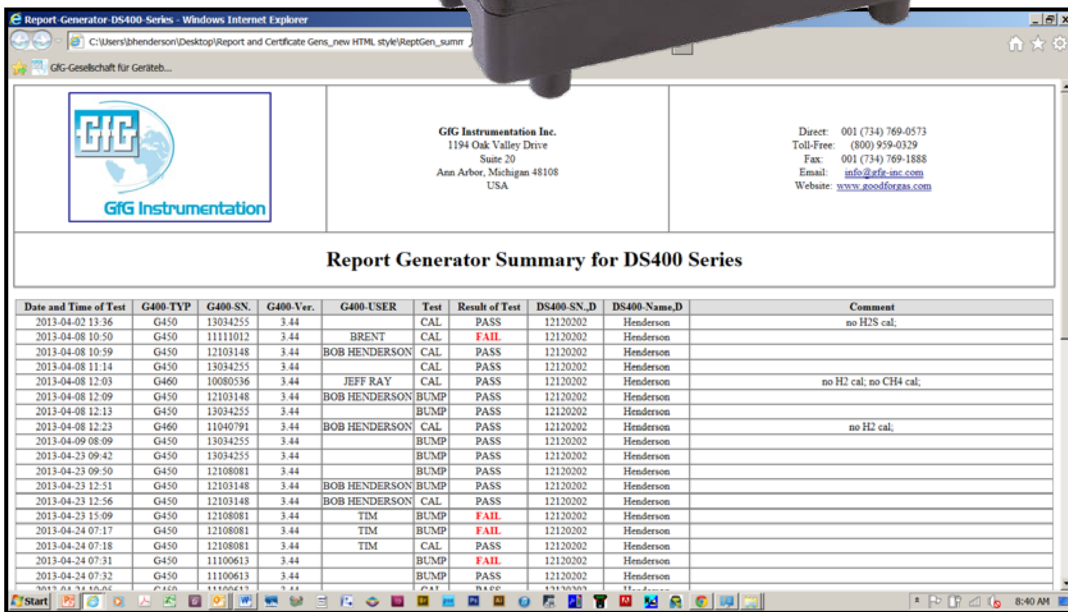
https://www.osha.gov/dts/shib/shib093013.html

Instruments should be tested by exposure to calibration gas on a regular basis!

- ***Gas detection instruments can only keep workers safe when they are maintained and used properly***
- ***Test by exposure to known concentration gas <u>before each day's use</u>***
- ***No exceptions!***

Docking stations

- *Make performing “Bump check” and “Calibration” easy and automatic*
- *Verifies readings are accurate*
- *Verifies audible alarms and LED alarms are properly activated when exposed to gas*
- *Documents the results*



Report-Generator-DS400-Series - Windows Internet Explorer

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Email: info@gfg-inc.com
Website: www.goodforgas.com

Report Generator Summary for DS400 Series

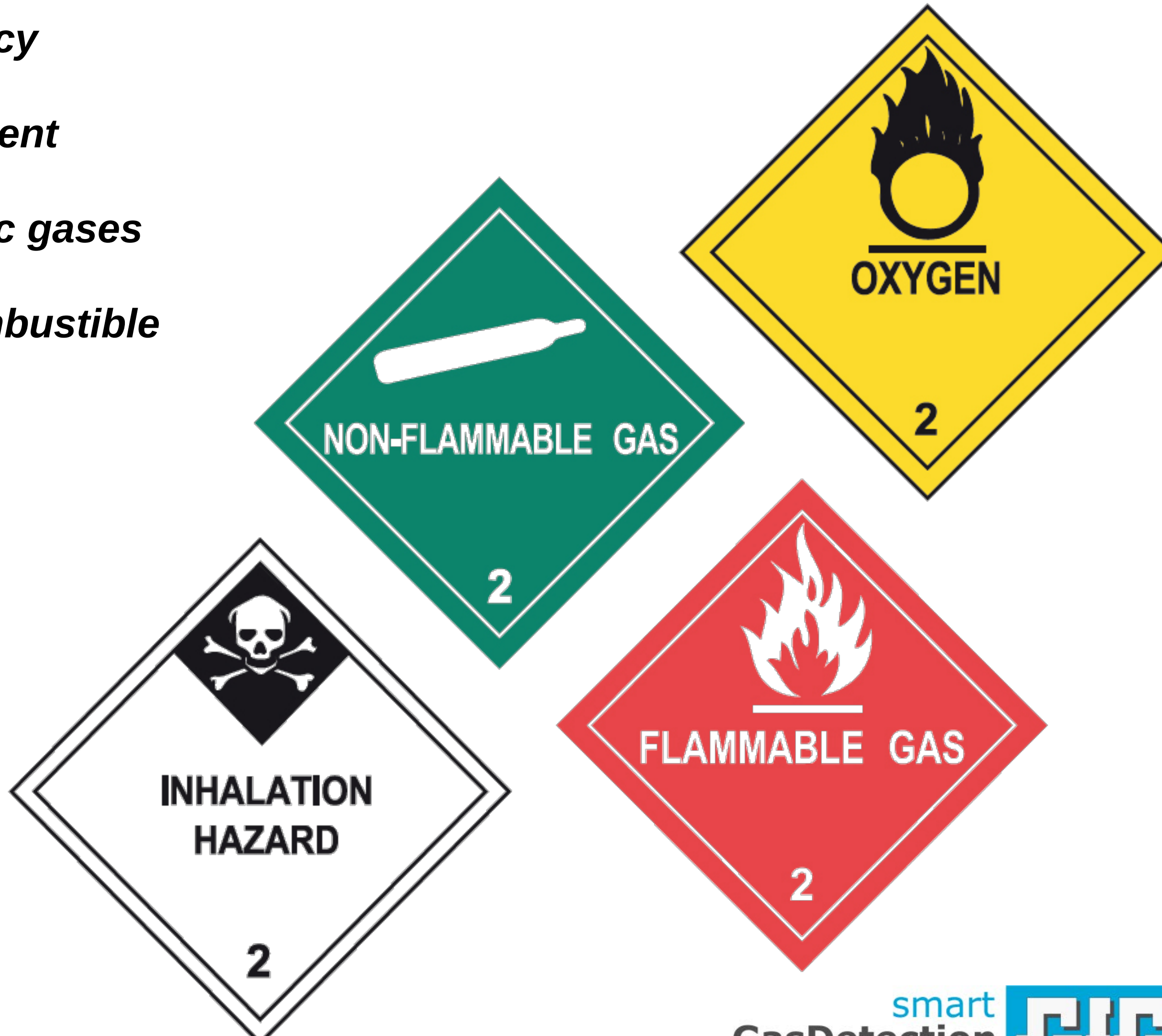
Date and Time of Test	G400-TYP	G400-SN.	G400-Ver.	G400-USER	Test	Result of Test	DS400-SN.,D	DS400-Name,D	Comment
2013-04-02 13:36	G450	13034255	3.44		CAL	PASS	12120202	Henderson	no H2S cal;
2013-04-08 10:50	G450	11111012	3.44	BRENT	CAL	FAIL	12120202	Henderson	
2013-04-08 10:59	G450	12103148	3.44	BOB HENDERSON	CAL	PASS	12120202	Henderson	
2013-04-08 11:14	G450	13034255	3.44		CAL	PASS	12120202	Henderson	
2013-04-08 12:03	G460	10080536	3.44	JEFF RAY	CAL	PASS	12120202	Henderson	no H2 cal; no CH4 cal;
2013-04-08 12:09	G450	12103148	3.44	BOB HENDERSON	BUMP	PASS	12120202	Henderson	
2013-04-08 12:13	G450	13034255	3.44		BUMP	PASS	12120202	Henderson	
2013-04-08 12:23	G460	11040791	3.44	BOB HENDERSON	CAL	PASS	12120202	Henderson	no H2 cal;
2013-04-09 08:09	G450	13034255	3.44		BUMP	PASS	12120202	Henderson	
2013-04-23 09:42	G450	13034255	3.44		BUMP	PASS	12120202	Henderson	
2013-04-23 09:50	G450	12108081	3.44		BUMP	PASS	12120202	Henderson	
2013-04-23 12:51	G450	12103148	3.44	BOB HENDERSON	BUMP	PASS	12120202	Henderson	
2013-04-23 12:56	G450	12103148	3.44	BOB HENDERSON	CAL	PASS	12120202	Henderson	
2013-04-23 15:09	G450	12108081	3.44	TIM	BUMP	FAIL	12120202	Henderson	
2013-04-24 07:17	G450	12108081	3.44	TIM	BUMP	FAIL	12120202	Henderson	
2013-04-24 07:18	G450	12108081	3.44	TIM	CAL	PASS	12120202	Henderson	
2013-04-24 07:31	G450	11100613	3.44		BUMP	FAIL	12120202	Henderson	
2013-04-24 07:32	G450	11100613	3.44		BUMP	PASS	12120202	Henderson	

Monitor and ventilate continuously

- ***Before entry it is mandatory to determine that the CS atmosphere is safe!***
- ***Many accidents result from changes in the CS atmosphere which occur <u>after</u> the entry is initiated***
- ***Monitoring determines the air is safe, ventilation keeps it that way***
- ***The only way to pick up changes before they become life threatening is to monitor continuously!***

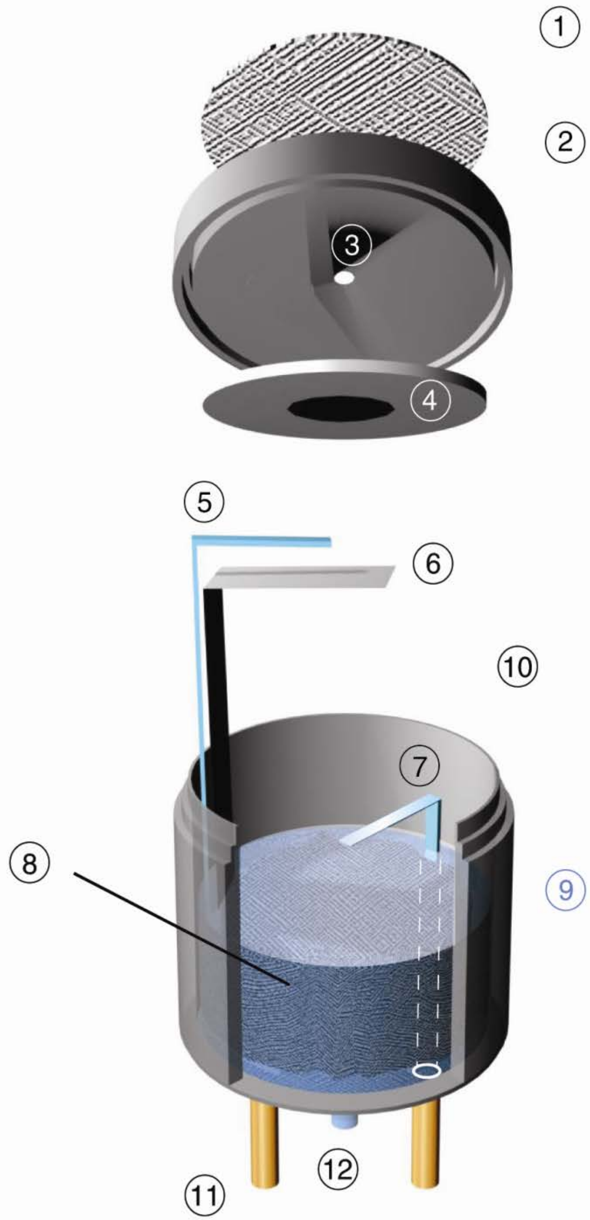
Common atmospheric hazards

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



Traditional O_2 sensor technology

Major components of a "fuel cell" type oxygen sensor



1. External Moisture Barrier
2. Diffusion Barrier
3. Diffusion Capillary
4. O_2 Sensing Electrode
5. Current Collector
6. Separator
7. Current Collector
8. Lead Annode (within electrolyte)
9. Electrolyte
10. Outer casing
11. Connector pins
12. Placement pin

Fuel cell type O_2 sensor failure mechanisms

- **Lower current output:**
  - **All available surface of Pb anode converted to PbO_2**
  - **Electrolyte leakage**
  - **Loss of structural integrity of housing**
  - **Desiccation**
  - **Blockage of capillary pore**
  - **Electrolyte poisoned by exposure to contaminants**
- **Test sensor before each day's use!**

Oxygen pump (lead free) sensor detection principle

- ***Oxygen passively diffuses into polymer (catalyst) substrate***
- ***Power from instrument battery used to "pump" the oxygen back out***
- ***Reactions: Oxidation / Reduction of target gas by catalyst***

$$\text{Sensing: } O_2 + 4H^+ + 4e^- \longrightarrow 2\,H_2O$$

$$\text{Counter: } 2\,H_2O \longrightarrow O_2 + 4H^+ + 4e^-$$

- ***Oxygen generated on counter electrode***
- ***Amount electricity required to remove reaction product and return sensor to ground state (by generating O_2 at counter electrode) proportional to concentration of oxygen present***

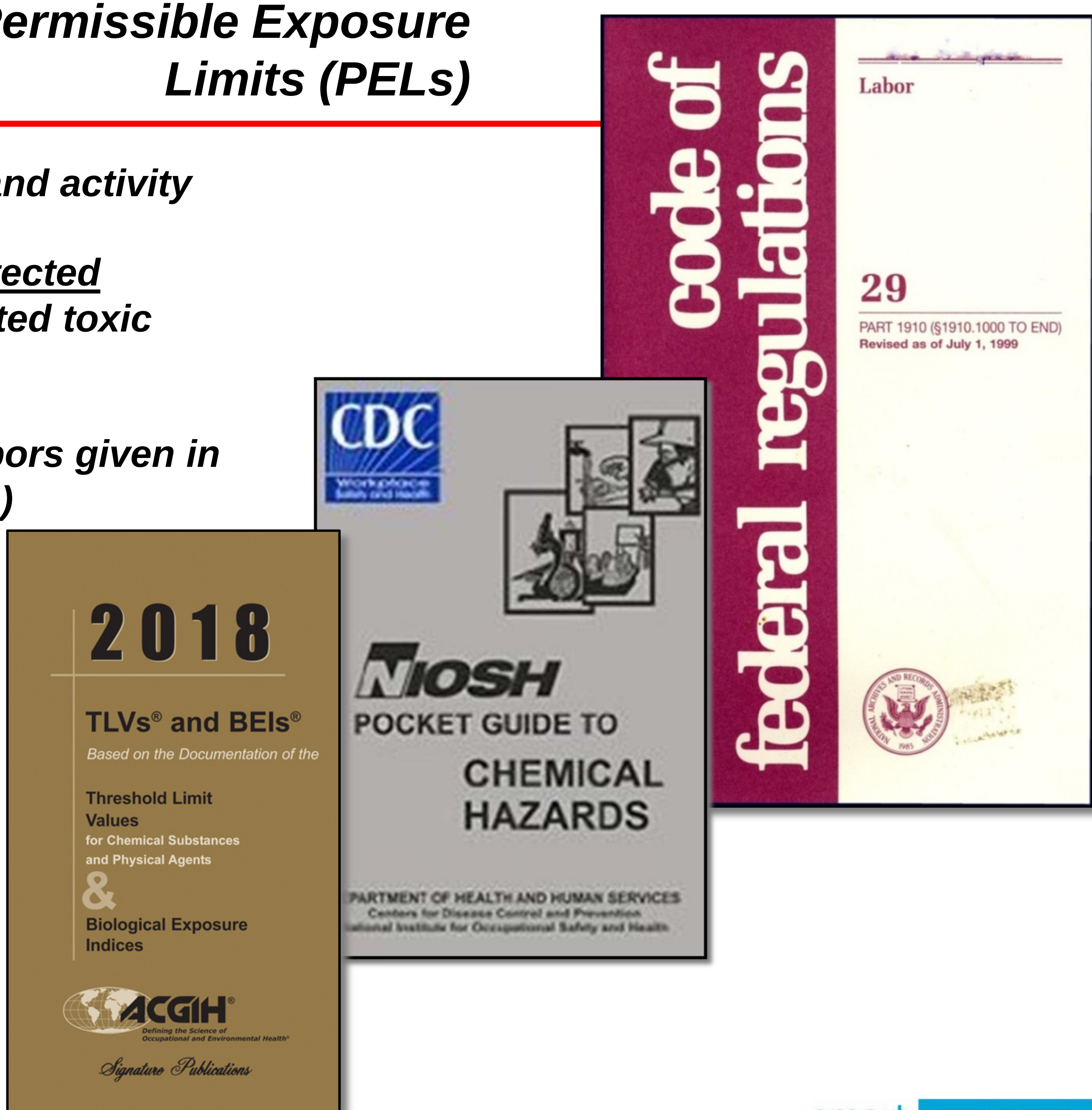
Toxic Gases and Vapors

- ***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)***
  - ***Carbon dioxide (CO_2)***
  - ***Chlorine (Cl_2)***
  - ***Ammonia (NH_3)***
  - ***Cyanide (HCN)***
  - ***Volatile organic chemicals (VOCs)***

Permissible Exposure Limits (PELs)

- *Depend on jurisdiction and activity*
- *PEL sets limit for <u>unprotected</u> worker exposure to a listed toxic substance*
- *Limits for gases and vapors given in "Parts-per-Million" (ppm) concentrations*
  - *1 % = 10,000 ppm*



Setting toxic sensor alarms

AP 1019: Setting the alarms in electrochemical sensor equipped toxic gas instruments

Recently lowered exposure limits have made taking a more conservative approach to setting alarms mandatory for many instrument users.

Recently lowered exposure limit guidelines for H_2S, SO_2 and NO_2 have forced many instrument users to revisit where to set the alarms in their atmospheric monitors. For other gases, although the exposure limits have not changed, corporate policies as well as enforcement agency decisions have made taking a more conservative approach mandatory for many instrument users.

- **Which exposure limits apply?**

The most important obligation for any employer is to ensure that workers are not harmed by exposure to toxic materials or conditions that may be present in the workplace environment. Exposure limits like the OSHA PEL, NIOSH REL and ACGIH® TLV® provide exposure limits, which if exceeded, may lead to immediate or long term harm. These guidelines and standards set the limits above which conditions are deemed to be hazardous. They are not necessarily the concentrations that should be used when setting alarms. For instrument users there are two obligations. The first is ensuring that workers are not exposed to hazardous conditions. The second is ensuring that workers are able to leave the affected area before becoming affected by a hazardous condition. Workers should be out of the area before rather than after the concentration of toxic gas exceeds the hazardous condition threshold. Unfortunately, the PEL, REL and TLV® are not always in agreement. Which exposure limit is applicable and enforceable depends on where you are, what you are doing, and who is responsible for enforcing your workplace safety requirements. Even when the applicable (and enforceable) hazardous condition threshold concentrations are unambiguous, setting the alarms can still be a challenge.

United States Occupational Safety and Health Administration (OSHA) regulations use the term Permissible Exposure Limit (PEL) to define the maximum concentration of a listed contaminant to which an unprotected worker may be exposed as an 8 hour time-weighted average (TWA) during the course of his workplace duties. Exposure limits for gases and vapors are usually given in units of parts-per-million (ppm). Limits for mists, fume and particulate solids are expressed in units of mg/m3. In addition to the 8 hour TWA PEL, Ceiling (C), Short Term Exposure Limit (STEL), and peak exposure limits are also specified for some airborne hazards.

OSHA 8 hour TWA PEL and C values are given for some airborne contaminants in Subpart Z (Section 1910.1000), and in substance-specific standards (e.g., methylene chloride, 1910.1052 and benzene, 1910.1028).

OSHA PELs are listed in Subpart Z (Section 1910.1000) of the Code of Federal Regulations, and posted at www.OSHA.gov. Individual states may either follow the Federal regulations, or if they have their own "Approved Occupational Safety and Health Plan" may follow their own, state-specific permissible exposure limits. States may not publish or follow exposure limits that are more permissive than Federal OSHA limits. Twenty-five states (as well as Puerto Rico and the Virgin Islands) have their own approved plan. In many cases the exposure limit in these states for a particular toxic substance is more conservative than the Federal OSHA PEL.

The National Institute of Occupational Safety and Health (NIOSH) develops and periodically revises recommended exposure limits (RELs) for hazardous substances or conditions in the workplace. The NIOSH REL is an occupational exposure limit that has been recommended by NIOSH to OSHA for adoption as a permissible exposure limit. The REL represents a level of exposure that NIOSH believes would be protective of worker safety and health over a working lifetime if used in combination with engineering and work practice controls. The OSHA PELs listed in Subpart Z are the same values originally promulgated in 1971. Because NIOSH RELs are periodically reviewed and updated, they tend to be more conservative than the OSHA exposure limits. Many states with approved occupational safety and health plans use the NIOSH RELs as the basis for their state specific permissible exposure limits. This

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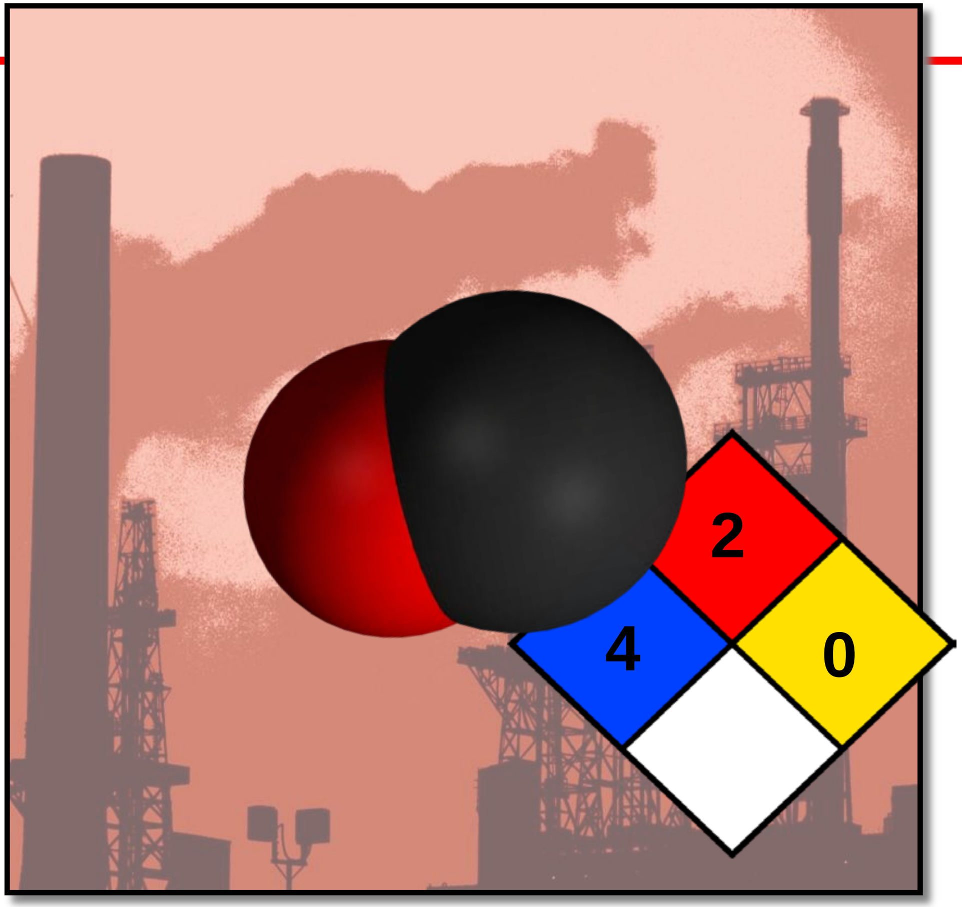
Exposure limits for carbon monoxide

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

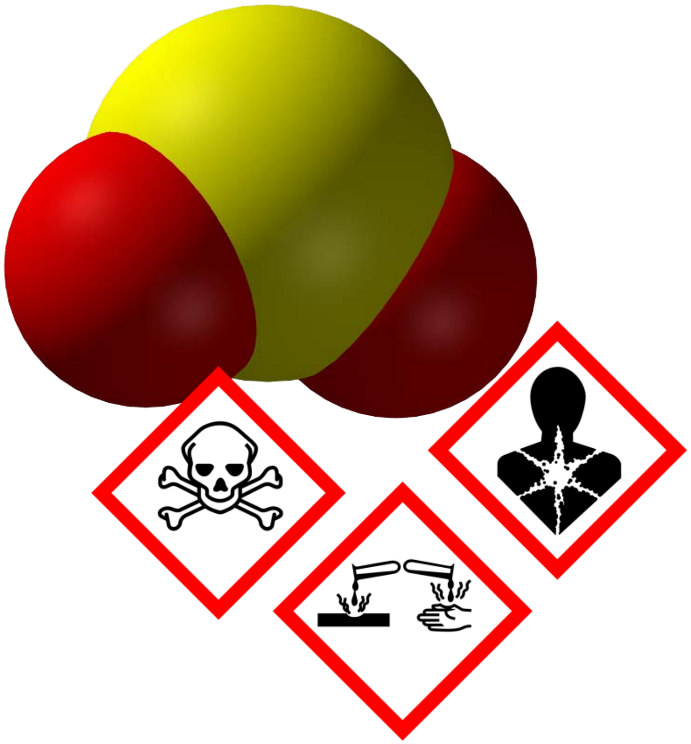


H_2S exposure limits

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*

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

- ***US OSHA PEL:***

  Ceiling = 5 ppm

- ***US NIOSH REL:***

  15 min. STEL = 1 ppm

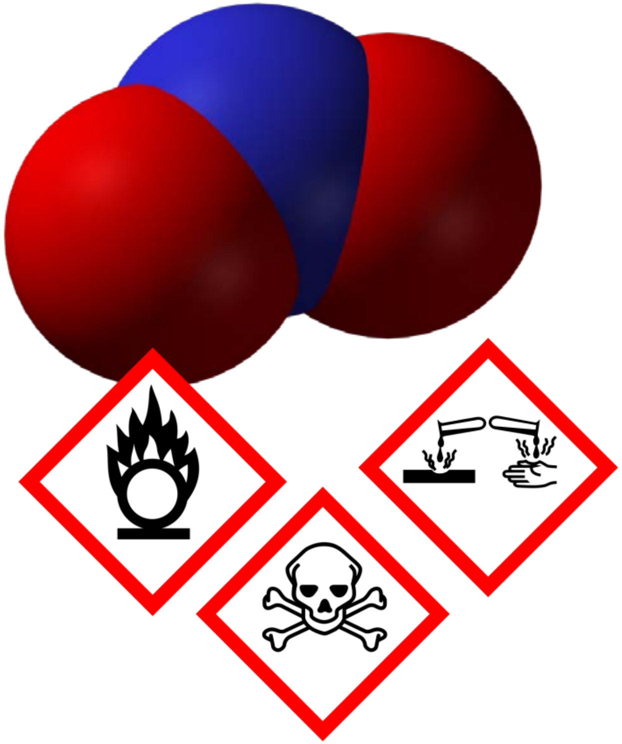
- ***Old TLV:***

  8 hr. TWA = 3 ppm

  5 min. STEL = 5 ppm

- ***New 2012 TLV***

  8 hr. TWA = 0.2 ppm



Measuring combustible gases and vapors

AP 1001:
Choosing the best detection technologies for measuring combustible gas and VOC vapors

No one single sensor (or type of sensor) is capable of detecting all types of dangerous gases and vapors. This is why workers who may be exposed to multiple hazards use instruments with multiple sensors installed.

The most commonly used sensors are for the measurement of combustible gas, oxygen, carbon monoxide and hydrogen sulfide. The majority of multi-sensor instruments are equipped with at least these four sensors. However, in many cases, these basic sensors are not capable of measuring all of the atmospheric hazards that are potentially present.

The sensors utilized in portable gas detectors are extremely good at detecting what they are designed to measure. The problem is that users are frequently unaware of the limitations, and use the sensors in ways that result in inaccurate readings. It is critically important for instrument users to understand what the sensors in their instrument cannot properly measure as well as what they can.

The good news is that there is an extremely wide range of technologies and types of sensors available for use in portable multi-sensor instruments. Just because one type of sensor does not work for a particular gas does not mean there are no alternatives. The only limitation is that the instrument must be sufficiently flexible to make use of the most appropriate detection technologies (Figures 1 and 2).

Oxygen, carbon monoxide and hydrogen sulfide sensors are designed to measure a single type of gas. There is very little ambiguity in the readings these sensors provide. The only

gas an oxygen sensor responds to is oxygen. Electrochemical
sensors designed to measure a partic
quite so specific. Although sensor manu
products to minimize responsiveness to
one they are supposed to measure, no
instance, carbon monoxide (CO) senso
to hydrogen as well as to the vapors p
solvents and other volatile organic che
most interfering effects are positive, th
sensor may occasionally provide higher th
CO is generally not regarded as a safety c
that workers leave the affected area a li
hydrogen sulfide (H_2S) sensor reading
exposure to degreasers and solvents s
citrus oil cleaners.

The sensor with the most important limita
"catalytic" or "pellistor" type percent
(% LEL) combustible gas sensor. In
of combustible sensor equipped atm
service around the world, there is still a
and misunderstanding when it comes
characteristics and limitations of this v
sensor.

**Figure 1: Flexibility to support the need
The G460 Multi-sensor Atmospheric
Instrumentation is capable of measuri
atmospheric hazards at the same time.**

USA and Canada	info@gfg-inc.com
Latin America	info@gfg-inc.com
Germany	info@gfg-mbh.com
South Africa	gfgsa@icon.co.za
Asia Pacific	info@gasdetection.asia
Europe	info@gfgeurope.com
Switzerland	info@gfg.ch

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Worldwide Manufacturer o

AP 1018:
Understanding catalytic LEL combustible gas sensor performance

In spite of the millions of combustible sensor equipped atmospheric monitors in service around the world, there is still a lot of misinformation and misunderstanding when it comes to the performance characteristics and limitations of this very important type of sensor. Understanding how combustible sensors detect gas is critical to correctly interpreting readings, and avoiding misuse of instruments that include this type of sensor.

The potential presence of combustible gases and vapors is one of the most common of all categories of atmospheric hazards. It stands to reason that the sensors used to measure combustible gases are the most widely used type of sensor included in portable atmospheric monitors; especially those used in confined space atmospheric monitoring procedures. In spite of the millions of combustible sensor equipped atmospheric monitors in service in the United States, there is still a lot of misinformation and misunderstanding when it comes to the performance characteristics and limitations of this very important type of sensor. Understanding how combustible sensors detect gas is critical to correctly interpreting readings, and avoiding misuse of instruments that include this type of sensor.

What do percent LEL combustible gas sensors measure?

In order for an atmosphere to be capable of burning explosively, four conditions must be met. The atmosphere must contain adequate oxygen, adequate fuel, a source of ignition, and sufficient molecular energy to sustain the fire chain reaction.

These four conditions are frequently diagrammed as the "Fire Tetrahedron". If any side of the tetrahedron is missing, incomplete or insubstantial; combustion will not occur.

The minimum concentration of gas or vapor in air that will ignite and explosively burn if a source of ignition is present is the Lower Explosive Limit. Different gases and vapors have different LEL concentrations. Below the LEL, the ratio of combustible gas molecules to oxygen is too low for combustion to occur. In other words, the mixture is "too lean" to burn.

Most (but not all) combustible gases and vapors also have an upper limit of concentration beyond which ignition will not occur. The Upper Explosion Limit or UEL is the maximum concentration of combustible gas or vapor in air that will support combustion. Above the UEL, the ratio of gas to oxygen is too high for the fire reaction to propagate. In other words, the mixture is "too rich" to burn. The difference in concentration between the LEL and UEL is commonly referred to as the Flammability Range. Combustible gas concentrations within the flammability range will burn or explode provided that the other conditions required in the fire tetrahedron are met.

Figure 1: : Multi-sensor portable instruments almost always include a sensor for measurement of combustible gas. The G460 is capable of being equipped with sensors designed to measure up to six different atmospheric hazards at the same time.

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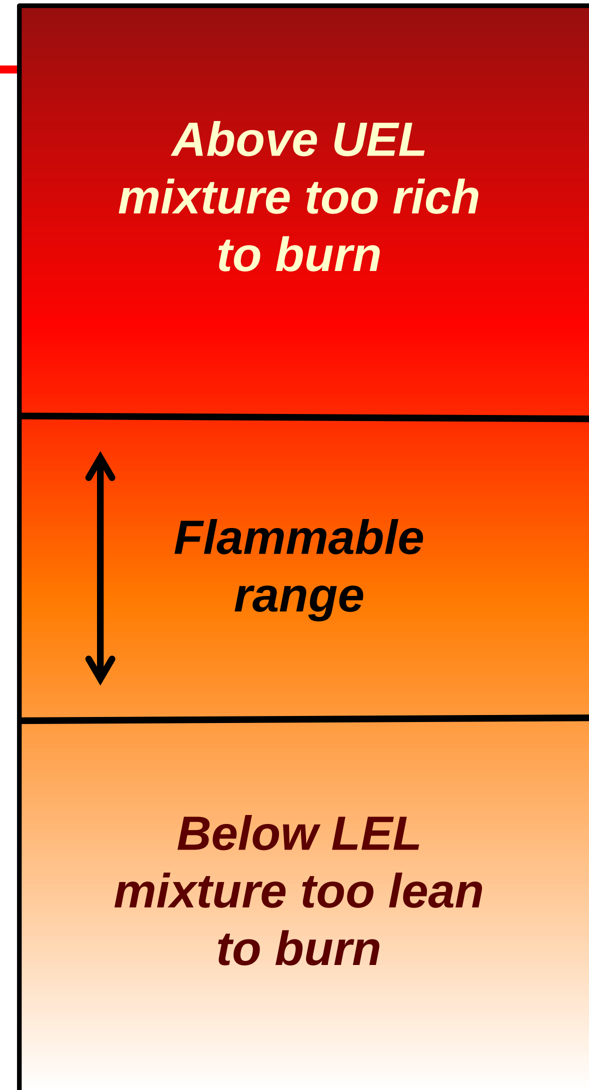
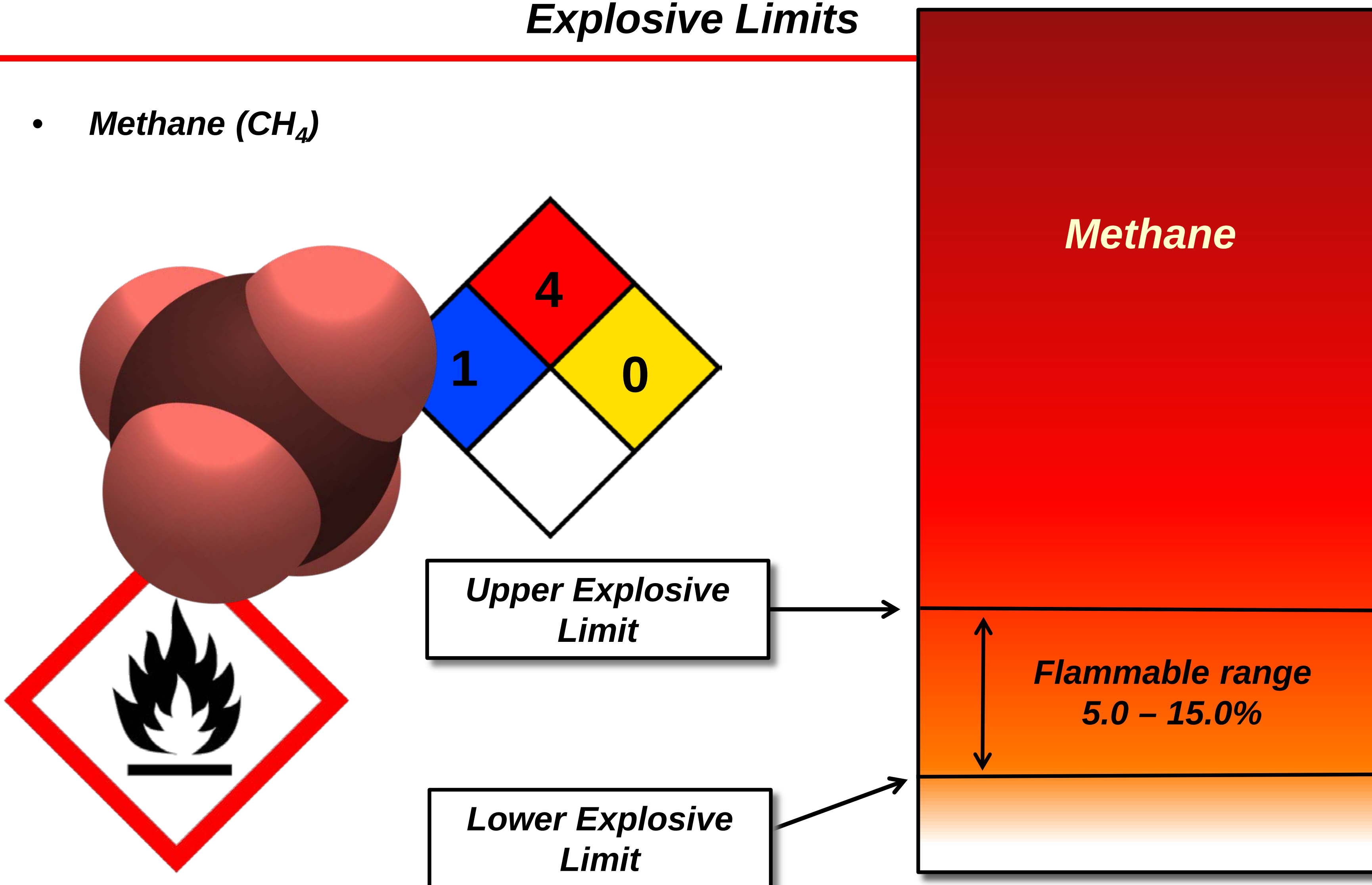
Explosive limits

- ***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***



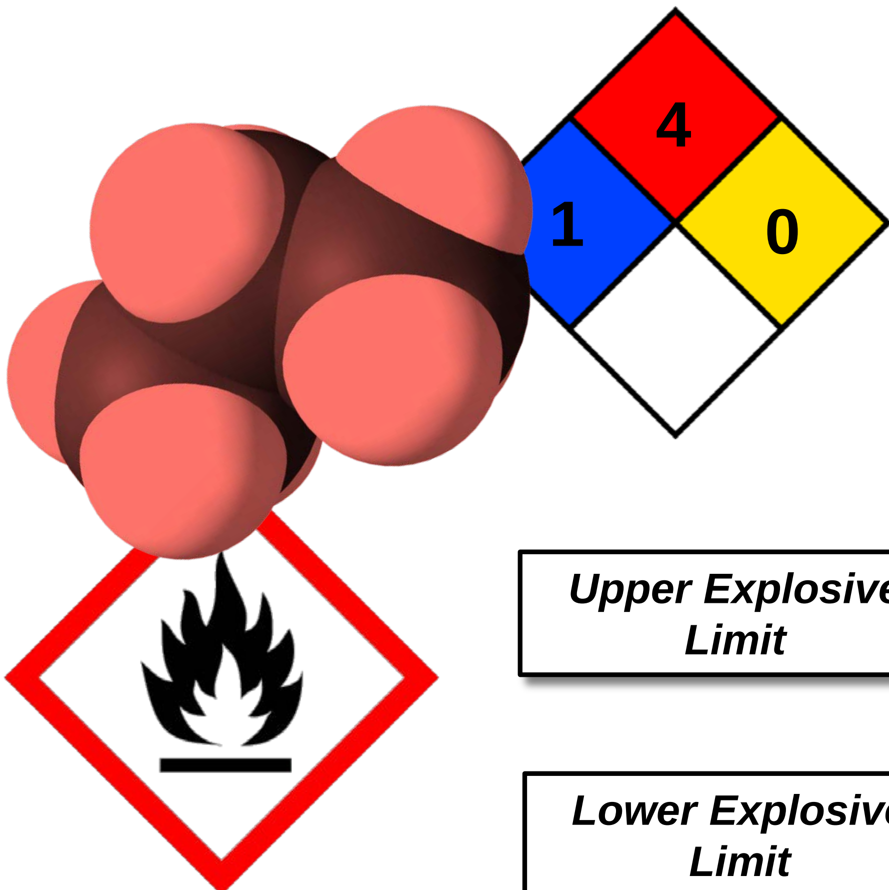
Explosive Limits

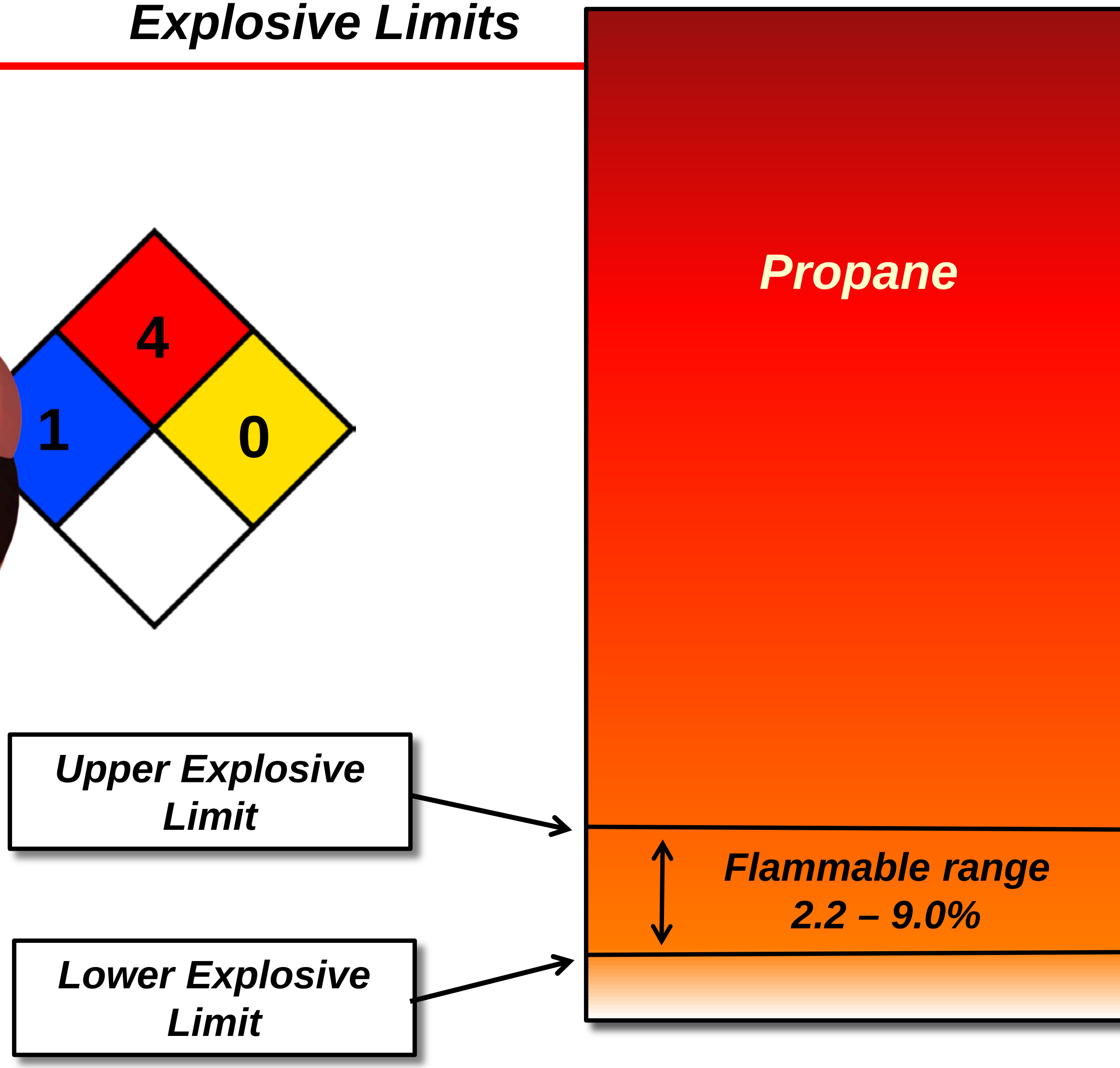
- ***Methane (CH_4)***



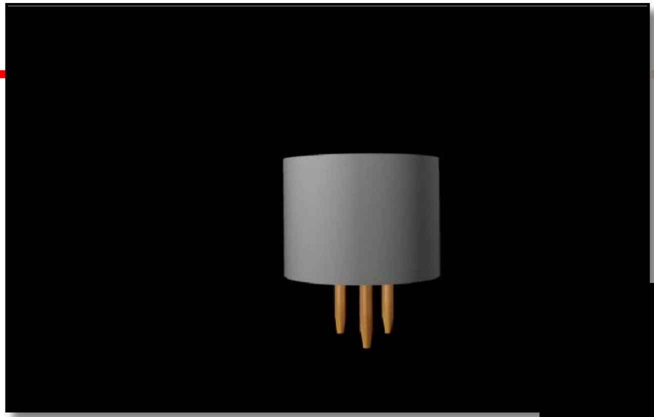
Explosive Limits

- ***Propane (C_3H_8)***

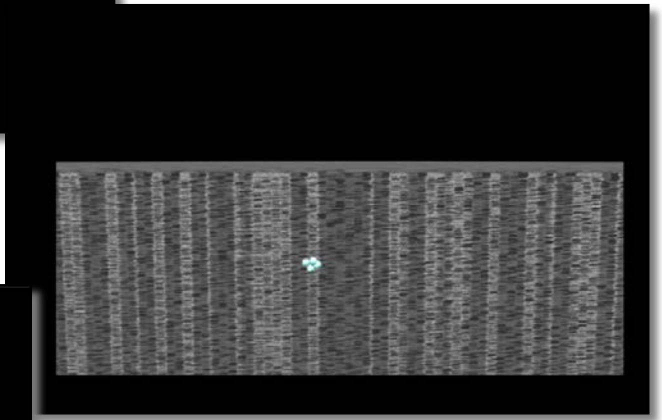




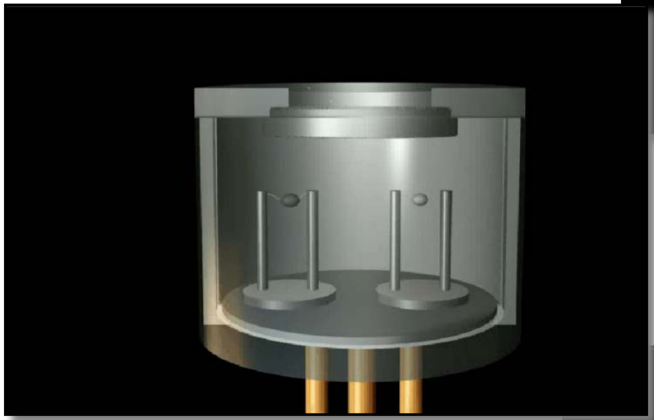
Catalytic Sensor Structure



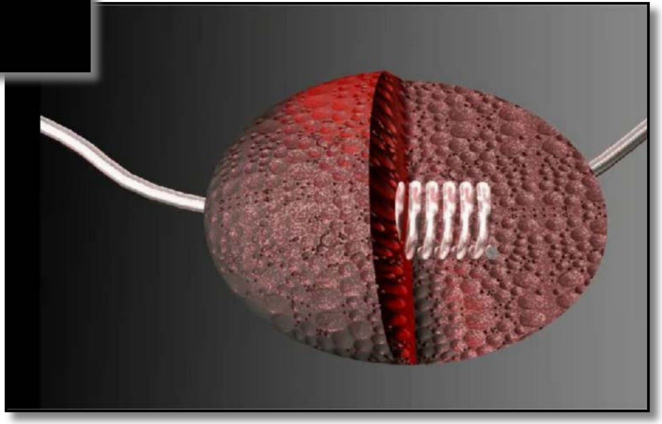
Catalytic combustion (CC) type LEL sensor is typically housed in robust, stainless steel flame proof enclosure



Gas molecules diffuse into sensor through flame arrestor

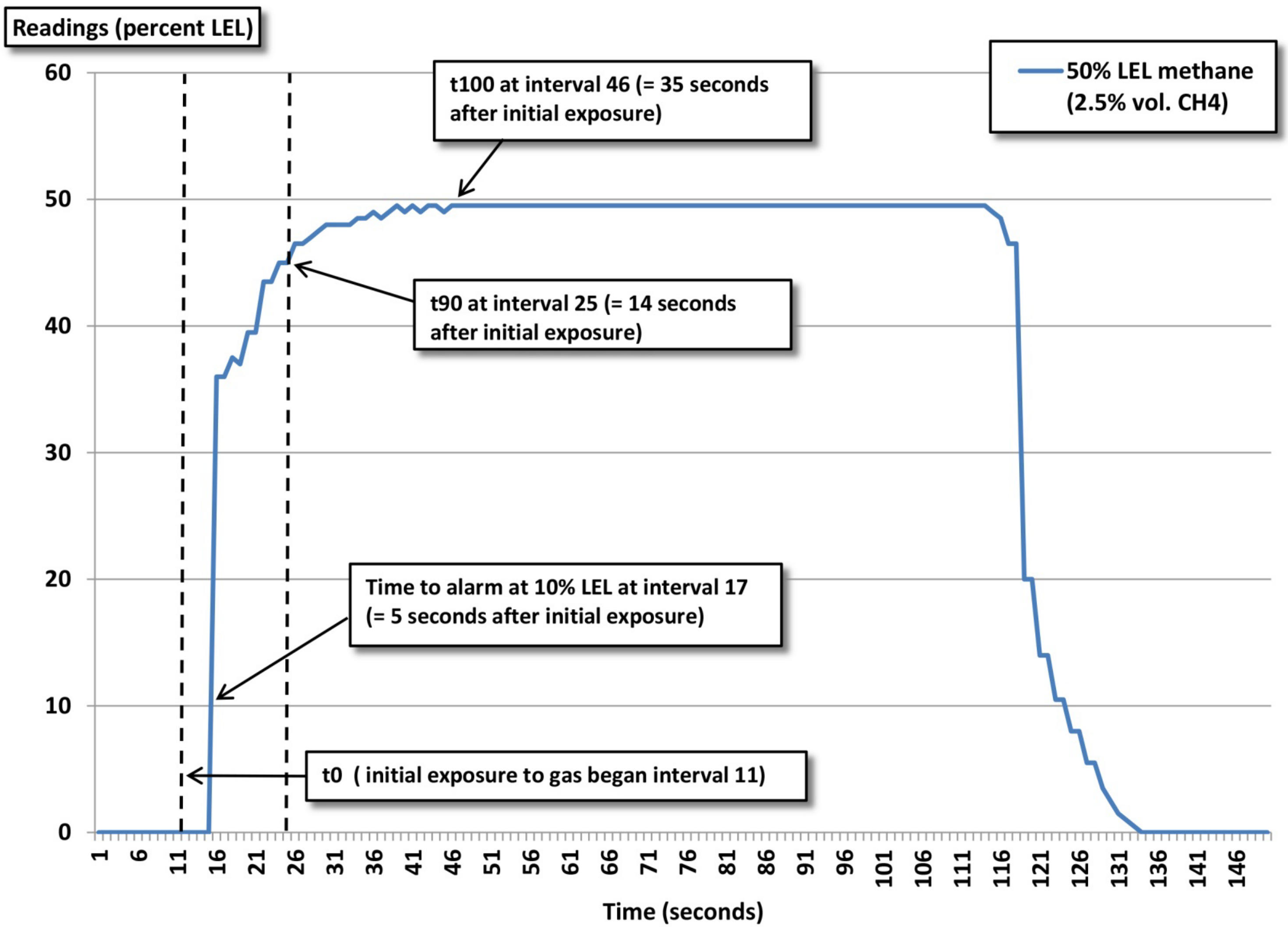


Once inside the sensor molecules diffuse to the active bead, where they are oxidized

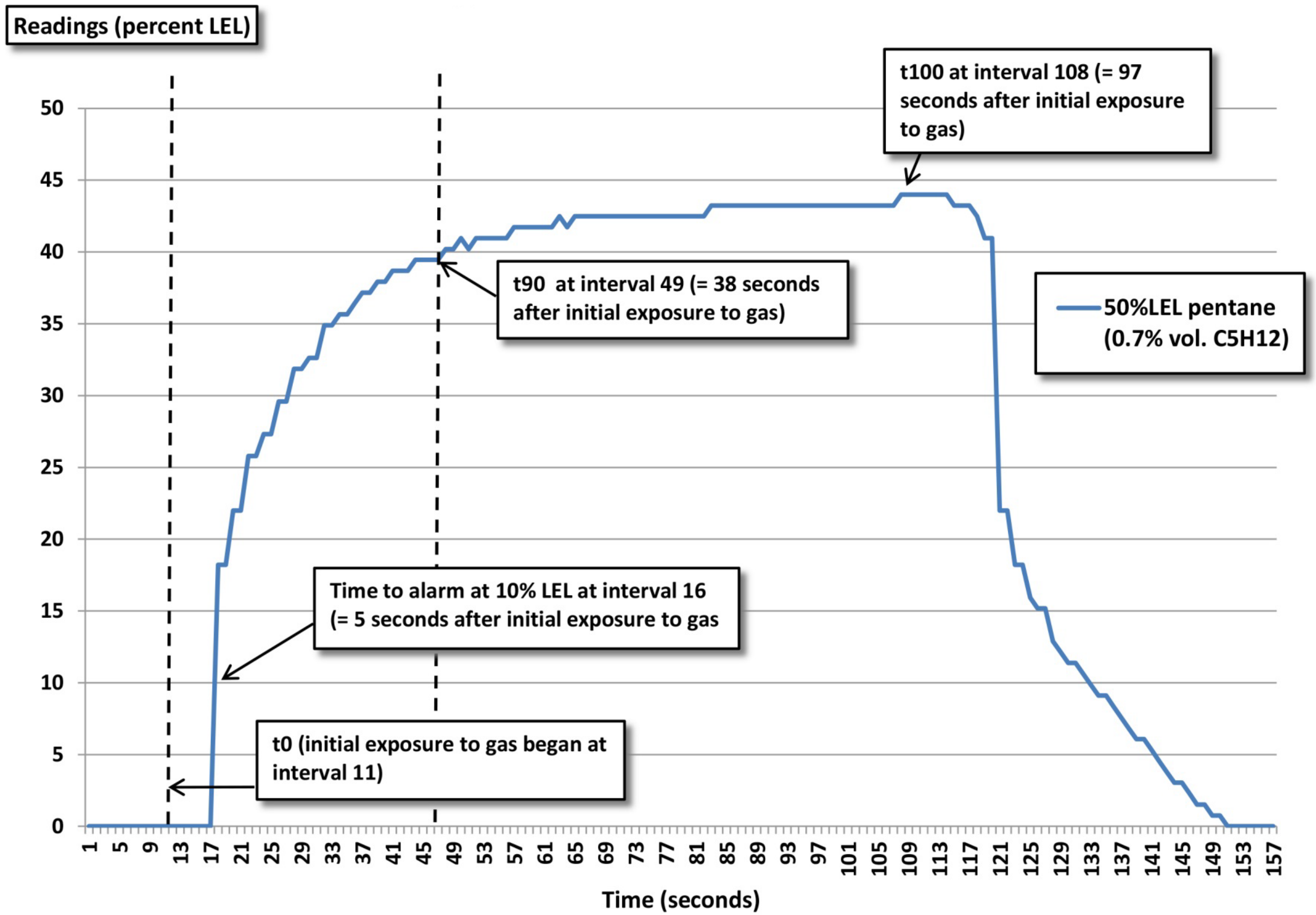


Oxidation heats active bead to higher temperature. Difference in temperature is proportional to the concentration of gas.

Typical catalytic percent LEL sensor response to 50% LEL methane (2.5% vol. CH_4)



Typical catalytic percent LEL sensor response to 50% LEL pentane (0.7% vol. C_5H_{12})



Combustible sensor poisons

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

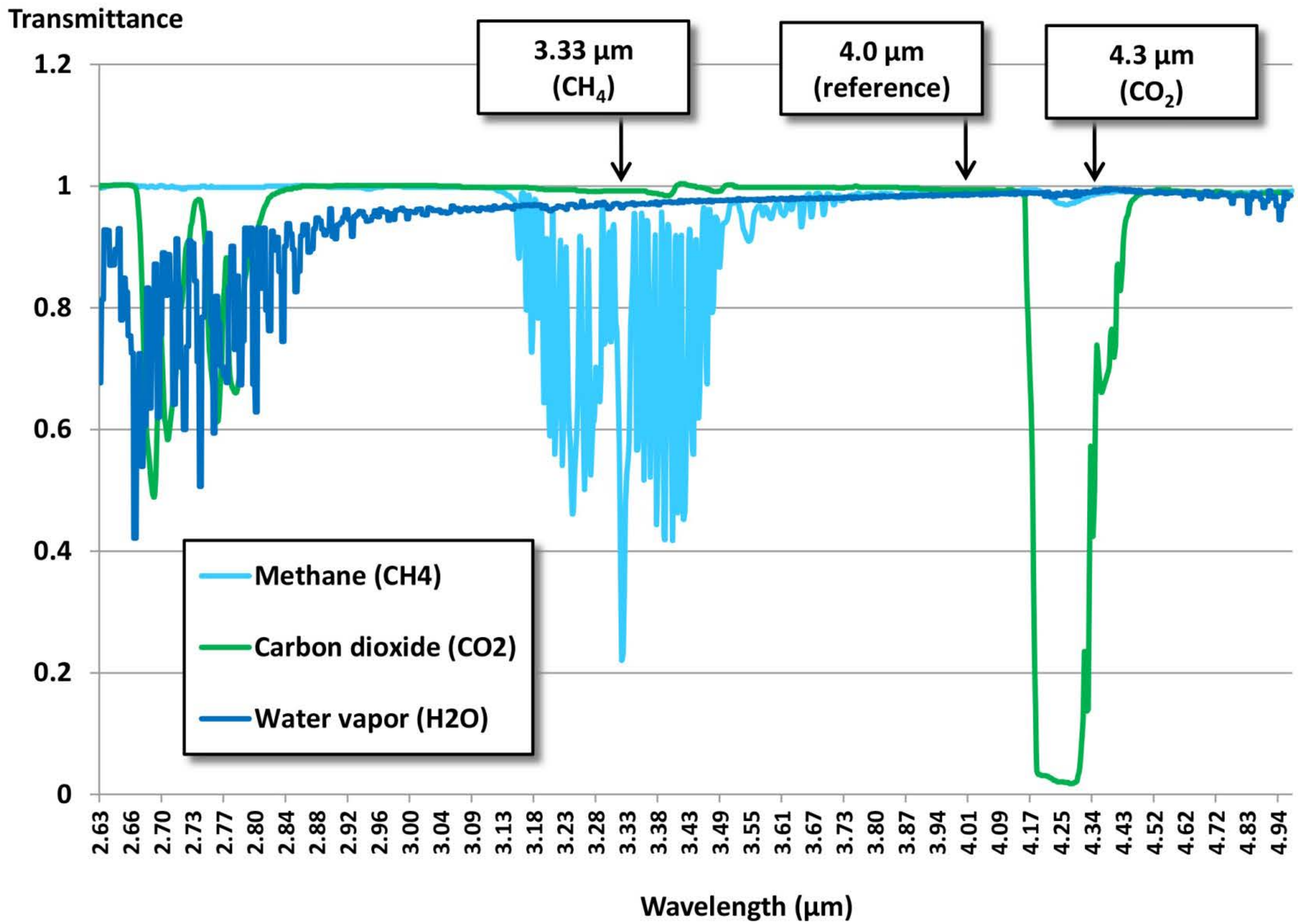
> ***Note: The LEL sensor includes an internal filter that is more than sufficient to remove the H_2S in calibration gas. It takes very high levels of H_2S to overcome the filter and harm the LEL sensor***

  - ***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.)***

Non-dispersive infrared (NDIR) sensors

- Many gases absorb infrared light at a unique wavelength
- In NDIR sensors the amount of IR light absorbed is proportional to the amount of target gas present
- IR absorption has advantages of high sensitivity, low cross-sensitivity, long life, and resistance to contamination

Infrared transmittance spectra for methane, water (vapor) and carbon dioxide (2.63 µm to 5.0 µm wavelength range)



Combustible gas NDIR sensor advantages and limitations

- ***Advantages:***
  - ***Sensor cannot be poisoned***
  - ***Does not require oxygen to detect gas***
  - ***Can be used for high-range combustible gas measurement***
  - ***Responds well to large hydrocarbon molecules that cannot be measured by means of standard LEL sensor***
- ***Limitations:***
  - ***Molecule must include chemical bonds that absorb at the wavelength(s) used for measurement***
  - ***Not all combustible gases can be detected!***
    - ***Hydrogen (H_2) <u>cannot be detected</u> at all***
    - ***Acetylene does not absorb at the wavelengths used in portable instruments***
    - ***Miniaturized low power IR LEL sensors with short optical path-lengths have <u>limited</u> ability to measure gases with lower relative responses***

Performance of IR LEL sensors differs from performance of catalytic LEL sensors

- ***Read the owner's manual!***
- ***Make sure to verify with manufacturer before attempting to use the sensor to measure unsaturated hydrocarbons, aromatic VOCs or other gases not specifically listed in the owner's manual!***

Appendix B

Detectable Combustible Gases

Gas[1]	Expected response at 20% LEL target gas[2]
Methane	20% LEL
Propane	15% LEL to 45% LEL
Butane	15% LEL to 35% LEL
Pentane	15% LEL to 45% LEL
Hexane	8% LEL to 28% LEL
Methanol/Ethanol[3]	6% LEL to 26% LEL
Hydrogen	No response
Acetylene	No response

[1]For any gases not listed, please contact Honeywell Analytics to find the best solution for your application.

[2]The BW Clip4 LEL sensor is optimized to see methane. While the unit can detect and respond to the other combustible gases listed in the above table, the accuracy of the readings may be in-consistent. If the primary need is to detect a specific combustible gas other than methane, please contact Honeywell Analytics to discuss an alternative product.

[3]Please use caution when using the BW Clip4 around Methanol and/or Ethanol. The BW Clip4 CO sensor may become inhibited by prolonged exposure to concentrations of Methanol and/or Ethanol thus causing the unit to alarm. This condition can last up to 12 hours before the CO sensor recovers to normal levels.

Photoionization Detectors

AP 1021:

Using photoionization detectors to measure toxic VOCs

VOCs present multiple potential threats in the workplace environment. Many VOC vapors are heavier than air, and can act to displace the atmosphere in an enclosed environment or confined space. Oxygen deficiency is a leading cause of injury and death in confined space accidents. The literature contains many examples of fatal accidents caused by oxygen deficiencies due to displacement by VOC vapors.

Most VOC vapors are flammable at low concentrations. For instance, the lower explosion limit (LEL) concentrations for toluene and hexane are only 1.1% (11,000 ppm). By comparison, it takes 5% volume methane (50,000 ppm) to reach an ignitable concentration in air. Because most VOCs produce flammable vapors, in the past, the tendency has been to measure them by means of combustible gas measuring instruments. Combustible gas reading instruments

- What are VOCs?

AP 1014:

Monitoring for Toxic VOCs in Oil Industry Applications

Increased awareness of the toxicity of VOC chemicals has led to lowered exposure limits, and increased requirements for direct measurement. Photoionization detector (PID) equipped instruments are increasingly viewed as the best choice for measurement of VOCs at exposure limit concentrations.

Organic chemicals consist of molecules that contain carbon. Volatile organic compounds (VOCs) are organic compounds characterized by their tendency to evaporate easily at room temperature.

Crude oil is a complex mixture that includes many different specific hydrocarbons and other chemicals. The hydrocarbons in crude oil are primarily alkanes, (molecules that consist entirely of carbon and hydrogen atoms), cycloalkanes (alkanes that include one or more rings in their structure), and various aromatic hydrocarbons (molecules that include a benzene ring in their structure). The molecules in crude oil present multiple potential hazards. Most of the gases and vapors associated with crude oil are highly flammable. Many hydrocarbon gases and vapors are heavier than air and can displace oxygen containing atmosphere in enclosed environments and confined spaces. In addition, many of the organic molecules associated with crude oil are highly toxic, with exposure limits (in some cases) of less than 1.0 ppm (8 hour TWA).

Toxic VOC exposure is a significant concern at many refineries, chemical plants and oil production facilities. Familiar substances containing VOCs include solvents, paint thinner and nail polish remover, as well as the vapors associated with fuels such as gasoline, diesel, heating oil, kerosene and jet fuel.

The category also includes specific toxic substances such as benzene, butadiene, hexane, toluene, xylenes, and many others. Most VOC vapors are flammable at surprisingly low concentrations. For most VOCs however, the toxic exposure limit is exceeded long before readings reach a concentration high enough to trigger a combustible range alarm.

Solvent, fuel and other VOC vapors are routinely encountered in many types of procedures undertaken at refineries, chemical plants and oil production facilities. VOC vapors are particularly associated with confined spaces and confined space entry procedures at these same facilities. In some cases the presence of VOCs is due to materials being used or stored in the confined space. In other cases, especially sewers and other large interconnected confined space networks, fuels, combustible liquids or other VOCs accidentally introduced in one location can easily spread to other locations within the system. Increased awareness of the toxicity of these common contaminants has led to lowered exposure limits, and increased requirements for direct measurement of these substances at their toxic exposure limit concentrations. Photoionization

Figure 1: Photoionization detector (PID) equipped instruments are increasingly viewed as the best choice for measurement of VOCs at exposure limit concentrations.

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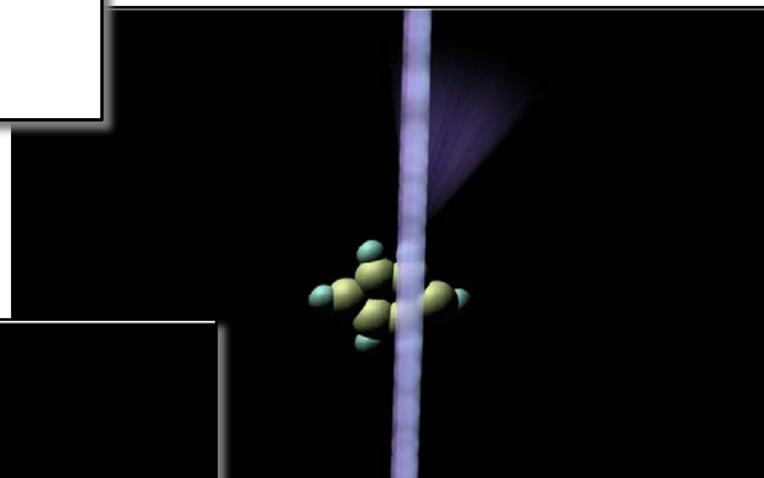
Why use photoionization detector equipped instruments?

- ***For most VOCs, long before you reach a concentration sufficient to register on a combustible gas indicator, you will have easily exceeded the toxic exposure limits for the contaminant***

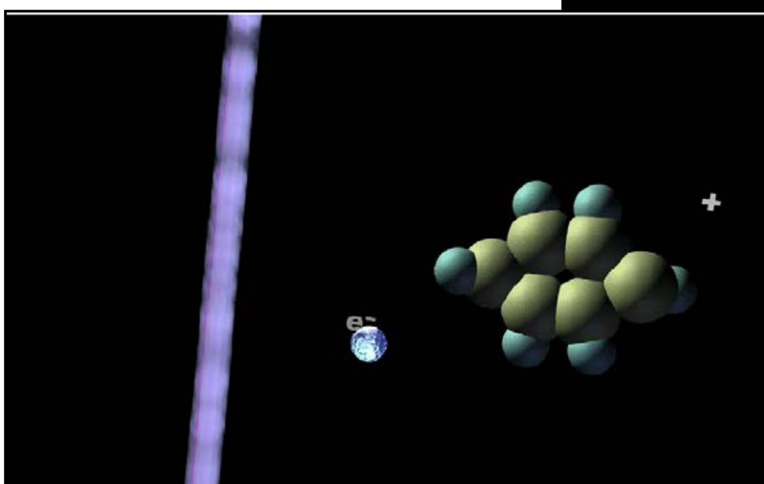
- ***PID equipped instruments are generally the best choice for measurement of VOCs at exposure limit concentrations***

How does a PID work?

PID sensor includes lamp used to generate beam of high energy photons of UV light



Molecules exposed to the beam of UV light



Detectable molecules are ionized, which means they lose an electron, producing an electrical flow proportional to concentration

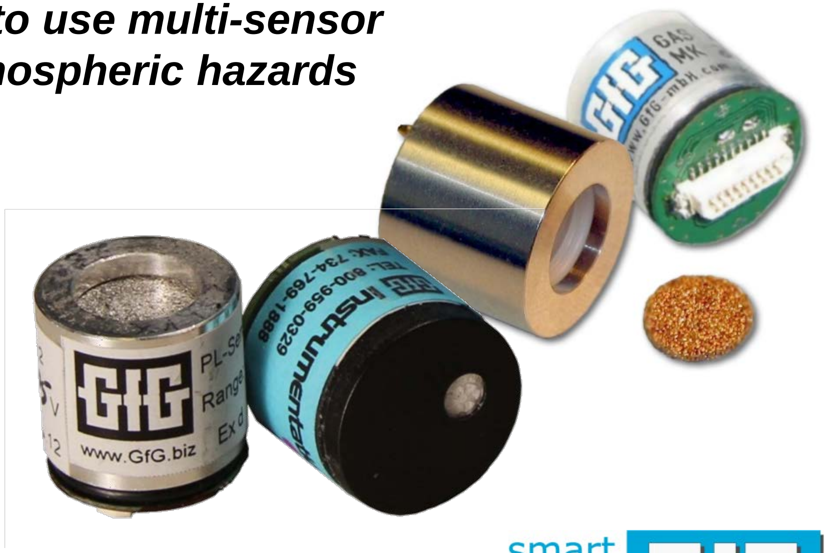
Catalytic (CC) LEL vs. PID Sensors

- ***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***



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Questions?

Thank you!

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